STANDARDIZATION RULES

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS

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STANDARDIZATION RULES

OF THE

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

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HISTORY OF THE STANDARDIZATION RULES.

The first step taken by the Institute toward the standardization of electrical apparatus and methods was a topical discussion on "The Standrdization of Generators, Motors and Transformers," which took place simultaneously in New York and Chicago on the evening of January 26, 1898. The discussion appears in the Institute TRANSACTIONS, Vol. XV, pages 3 to 32. The opinions expressed were generally favorable to the scheme of standardization of electrical apparatus, although some members feared that difficulties might arise. As a result of this discussion, a Committee on Standardization was appointed by the Council of the Institute, consisting of the following members:

FRANCIS B. CROCKER, *Chairman*.

CARY T. HUTCHINSON	CHARLES P. STEINMETZ
ARTHUR E. KENNELLY	LEWIS B. STILLWELL
JOHN W. LIEB, JR.	ELIHU THOMSON

After a careful consideration of the matter and consultation with the members of the Institute and interested parties generally, a "Report of the Committee on Standardization," was presented and accepted by the Institute, June 26, 1899. Those original rules appeared in the Institute TRANSACTIONS, Vol. XVI, pages 255 and 268.

As a result of changes and developments in the electric art, it was subsequently found necessary to revise the original report, this work being carried out by the following Committe on Standardization:

FRANCIS B. CROCKER, *Chairman*.

ARTHUR E. KENNELLY	CHARLES P. STEINMETZ
JOHN W. LIEB, JR.	LEWIS B. STILLWELL
C. O. MAILLOUX	ELIHU THOMSON

This revised report was adopted at the 19th Annual Convention at Great Barrington, Mass., on June 20, 1902, and appears in the Institute TRANSACTIONS, Vol. XIX, pages 1075 to 1092.

In consequence of still further change and development in electrical apparatus and methods, it was decided in September, 1905 that a second revision was needed, and the following C mmittee was appointed to do this work.

FRANCIS B. CROCKER, *Chairman*.
ARTHUR E. KENNELLY, *Secretary*.

HENRY S. CARHART	CHARLES F. SCOTT
JOHN W. LIEB, JR.	CHARLES P. STEINMETZ
C. O. MAILLOUX	HENRY G. STOTT
ROBERT B. OWENS	S. W. STRATTON

This Committee held monthly meetings and carried on extensive correspondence with manufacturers, consulting and operating engineers and other interested parties, and as a result, presented its report at the 23d Annual Convention, held at Milwaukee, May 28–30, 1906. After considerable discussion the report was accepted and referred back to the Committee for amendment and rearrangement in form. It was then to be submitted to the Board of Directors for final adoption. In September, 1906, the following Standardization Committee was appointed:

FRANCIS B. CROCKER, *Chairman.*
ARTHUR E. KENNELLY, *Secretary.*

A. W. BERRESFORD	CHARLES F. SCOTT
DUGALD C. JACKSON	CHARLES P. STEINMETZ
C. O. MAILLOUX	HENRY G. STOTT
ROBERT B. OWENS	S. W. STRATTON

ELIHU THOMSON

This Committee held monthly meetings, also sub-committee meetings, and carefully referred the rules as a whole, and each part of them to the members of the Institute. The rules were also entirely rearranged as to form, and put in shape to facilitate ready reference to them and enable future revisions to be made without breaking up the logical arrangement. Thus amended the rules were submitted to the Board of Directors and approved by it on June 21, 1907. The Board also directed that the rules should be presented, as accepted by the Board, at the Annual Convention held at Niagara Falls, June 24 to 27, 1907, which action was taken by President Sheldon on June 26, 1907. By the Constitution which went into effect on June 10, 1907, this Committee has been made a standing Committee with the title "Standards Committee," consisting of nine members.

On August 12, 1910 the Board of Directors increased the size of the committee from nine to twelve members; on October 14 from twelve to fourteen, and on March 10, 1911 from fourteen to sixteen. The committee thus constituted is given below.

COMFORT A. ADAMS, *Chairman.*
ARTHUR E. KENNELLY, *Secretary.*

H. W. BUCK	W. S. MOODY
GANO DUNN	R. A. PHILIP
H. W. FISHER	W. H. POWELL
H. B. GEAR	CHARLES ROBBINS
J. P. JACKSON	E. B. ROSA
W. L. MERRILL	CHARLES P. STEINMETZ
RALPH D. MERSHON	CALVERT TOWNLEY

This committee and several sub-committees held numerous meetings at which the general revision of the Standardization Rules of the Institute was considered. The complete Standardization Rules as revised by this committee, were presented to and approved by the Board of Directors on June 27th, 1911, at the Annual Convention held at Chicago, Ill.

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GENERAL PLAN.

STANDARDIZATION RULES OF THE A. I. E. E.

As Approved June 27, 1911.

I. DEFINITIONS AND TECHNICAL DATA.

1 *Note.* The following definitions and classifications are intended to be practically descriptive and not scientifically rigid.

A. DEFINITIONS, CURRENTS AND E.M.F.'S.

2 A Direct Current is a unidirectional current.

3 A Continuous Current is a steady, or non-pulsating, direct current.

4 A Pulsating Current is a current equivalent to the superposition of an alternating current upon a continuous current.

5 An Alternating Current or e.m.f. is a current or e.m.f. which, when plotted against time in rectangular coordinates, consists of half-waves of equal area in successively opposite directions from the zero line.

5a Cycle. Two immediately succeeding half-waves constitute a cycle.

5b Period. The time required for the execution of a cycle is called a period.

5c Frequency. The number of cycles per second is called the frequency.

5d Wave-form. The shape of the curve of e.m.f. or current plotted against time in rectangular coördinates, is ordinarily referred to as the wave-form or wave-shape. Two alternating quantities are said to have the same wave-shape if their corresponding phase ordinates bear a constant ratio. The wave-shape, as ordinarily understood, is thus independent of the scales to which the curve is plotted.

5e Simple Alternating Wave. Unless otherwise specified an alternating current or e.m.f. is assumed to be sinusoidal, and the wave a sinusoid, sine-wave or curve of sines. On this account a complete cycle is taken as 360 degrees, and any portion of a cycle may be expressed in degrees from any convenient reference point, such as the ascending zero-point.

5f A Complex Alternating Wave is a non-sinusoidal wave. A complex alternating wave is capable of being resolved into a single sine wave of fundamental frequency, with superposed odd-frequency harmonic waves, or ripples, of 3, 5, 7 . . . $(2n+1)$ times the fundamental frequency, each harmonic having constant amplitude, and a definite starting phase-relation to the fundamental sine-wave. It is customary when analyzing a complex wave, to neglect harmonics higher than the 11th; *i.e.*, of frequency higher than 11 times the fundamental. In special cases, however, frequencies still higher may have to be considered. In certain exceptional cases even harmonics are present.

5g Root-Mean-Square Value (sometimes called the Virtual or Effective Value). Unless otherwise specified, the rating of an alternating current or e.m.f., in amperes or volts, is assumed to be the square root of the mean square value taken throughout one or more complete cycles. This is sometimes abbreviated to r.m.s. The term root-mean-square is to be preferred to the terms virtual or effective. The root-mean-square value is indicated by all properly calibrated alternating-current voltmeters and ammeters. In the case of a sine-wave, the ratio of the maximum to the r.m.s. value is $\sqrt{2}$.

5h FORM-FACTOR OF AN ALTERNATING WAVE. The ratio of the root-mean-square to the arithmetical mean ordinate of a wave, taken without regard to sign, is called its form-factor. The form-factor for a purely rectangular wave is the minimum, 1.0; for a sine wave it is 1.11, and for a wave more peaked than a sine wave it is greater than 1.11.

5i THE EQUIVALENT SINE WAVE is a sine wave having the same frequency and the same r.m.s value as the actual wave.

5j The DEVIATION of wave-form from the sinusoidal is determined by superposing upon the actual wave, (as determined by oscillograph), the equivalent sine wave of equal length, in such a manner as to give the least difference, and then dividing the maximum difference between corresponding ordinates by the maximum value of the equivalent sine wave.

5k PHASE DIFFERENCE. When corresponding cyclic values of two sinusoidal alternating quantities such as two alternating currents or e.m.fs. or of a current and an e.m.f., of the same frequency, occur at different instants, the two alternating quantities are said to differ in phase, their phase difference being the time interval, expressed in degrees or as a fraction of a cycle, between the occurrence of their corresponding values; *e.g.* their ascending zeros or their positive maxima.

5l EQUIVALENT PHASE DIFFERENCE. If two alternating quantities are non-sinusoidal, and of different wave shapes, the preceding definition of phase-difference is inapplicable, and phase-difference ceases to have exact significance. However, when the two complex alternating quantities are the voltage E and current I in a given circuit, the effective power P of which is known, it is customary to define the equivalent phase difference by the angle whose cosine is the power-factor, P/EI, of the circuit. See Sections 54 and 324.

5m SINGLE-PHASE. A term characterizing a simple alternating current circuit energized by a single alternating e.m.f. Such a circuit is usually supplied through two wires. The currents in these two wires counted positively outwards from the source, differ in phase by 180 degrees or half a cycle.

5n THREE-PHASE. A term characterizing the combination of three circuits energized by alternating e.m.fs. which differ in phase by one third of a cycle; *i.e.*, 120°.

5o QUARTER-PHASE, also called TWO-PHASE. A term characterizing the combination of two circuits energized by alternating e.m.fs. which differ in phase by a quarter of a cycle; *i.e.*, 90°.

5p SIX-PHASE. A term characterizing the combination of six circuits energized by alternating e.m.fs. which differ in phase by one sixth of a cycle; *i.e.*, 60°.

5q POLYPHASE is the general term applied to any alternating system with more than a single phase.

6 An OSCILLATING CURRENT is a current alternating in direction, and of decreasing amplitude.

B. DEFINITIONS. ROTATING MACHINES.

7 A GENERATOR transforms mechanical power into electrical power.

8 A DIRECT-CURRENT GENERATOR produces a direct current that may or may not be continuous.

9 An ALTERNATOR is an alternating-current generator, either single-phase or polyphase.

9a A SYNCHRONOUS ALTERNATOR comprises a constant magnetic field and an armature delivering either single-phase or polyphase current in synchronism with the rotation of the machine.

10 A POLYPHASE GENERATOR produces currents differing symmetrically in phase; such as quarter-phase currents, in which the terminal voltages of the two circuits differ in phase by 90 degrees; or three-phase currents, in which the terminal voltages of the three circuits differ in phase by 120 degrees.

11 A DOUBLE-CURRENT GENERATOR supplies both direct and alternating currents from the same armature-winding.

11a AN INDUCTOR ALTERNATOR is an alternator in which both field and armature windings are stationary.

11b AN INDUCTION GENERATOR is a machine structurally identical with an induction motor, but driven above synchronous speed as an alternating-current generator.

12 A MOTOR transforms electrical power into mechanical power.

12a A DIRECT-CURRENT MOTOR transforms direct-current power into mechanical power.

12b AN ALTERNATING-CURRENT MOTOR transforms alternating-current power into mechanical power.

12c A SYNCHRONOUS MOTOR is a machine structurally identical with a synchronous alternator, but operated as a motor.

12d A SYNCHRONOUS PHASE MODIFIER, sometimes called a Synchronous Condenser, is a synchronous motor, running either idle or under load, whose field excitation may be varied so as to modify the power-factor of the circuit, or through such modification to influence the voltage of the circuit.

12e AN INDUCTION MOTOR is an alternating-current motor, either single-phase or polyphase, comprising independent primary and secondary windings, one of which, usually the secondary, is on the rotating member. The secondary winding has no conductive connection with the supply circuit.

12f A REPULSION MOTOR is an induction motor, usually single phase, in which the magnetic axis of the secondary, (a closed coil winding mounted on the rotor), is maintained at a certain fixed angle with respect to the stationary primary coil by means of a multisegmental commutator and short-circuiting brushes.

12g A SINGLE-PHASE SERIES COMMUTATOR MOTOR is structurally similar to a series direct-current motor, except that it is usually provided in addition with a series compensating winding distributed around the outer air-gap periphery and supported in slots in the pole faces, for the purpose of diminishing the armature leakage reactance.

13 A BOOSTER is a machine inserted in series in a circuit to change its voltage. It may be driven by an electric motor (in which case it is termed a motor-booster) or otherwise.

14 A MOTOR-GENERATOR is a transforming device consisting of a motor mechanically connected to one or more generators.

15 A DYNAMOTOR is a transforming device combining both motor and generator action in one magnetic field, either with two armatures, or with one armature having two separate windings and independent commutators.

16 A CONVERTER is a machine employing mechanical rotation in changing electrical energy from one form into another. A converter may belong to either of several types, as follows:

17 *a.* A DIRECT-CURRENT CONVERTER converts from a direct current to a direct current, usually with a change of voltage.

18 *b.* A SYNCHRONOUS CONVERTER (commonly called a rotary converter) converts from an alternating to a direct current, or *vice versa*.

19 *c.* A MOTOR-CONVERTER is a combination of an induction motor with a synchronous converter, the secondary of the former feeding the armature of the latter with current at some frequency other than the impressed frequency; *i.e.*, it is a synchronous converter concatenated with an induction motor.

20 *d.* A FREQUENCY CHANGER converts the power of an alternating-current system from one frequency to another, with or without a change in the number of phases or in the voltage.

21 *e.* A ROTARY PHASE CONVERTER converts from an alternating-current system of one or more phases to an alternating-current system of a different number of phases, but of the same frequency.

21a EQUALIZING CONNECTIONS are low resistance connections between equipotential points of multiple-wound closed-coil armatures to equalize the induced voltage between brushes.

C. DEFINITIONS. STATIONARY INDUCTION APPARATUS.

22 STATIONARY INDUCTION APPARATUS changes electric energy to electric energy through the medium of magnetic energy. It comprises several forms, distinguished as follows:

23 *a*. TRANSFORMERS, in which the primary and secondary windings are insulated from one another.

23a A PRIMARY WINDING is that winding of a transformer, or of an induction motor, which receives power from an external source.

23b A SECONDARY WINDING is that winding of a transformer, or of an induction motor, which receives power from the primary by induction.

Note: The terms "High-voltage winding" and "Low-voltage winding" are suitable for distinguishing between the windings of a transformer, where the relations of the apparatus to the source of power are not involved.

24 *b*. AUTO-TRANSFORMERS, also called compensators, in which a part of the primary winding is used as a secondary winding, or conversely.

25 *c*. POTENTIAL REGULATORS, in which one coil is in shunt and one in series with the circuit, so arranged that the ratio of transformation between them is variable at will. They are of the following three classes:

26 1. CONTACT VOLTAGE REGULATORS, also called Compensator Regulators, in which the number of turns in use of one of the coils is adjustable.

27 (2) INDUCTION POTENTIAL REGULATORS in which the relative positions of the primary and secondary coils are adjustable.

28 (3) MAGNETO POTENTIAL REGULATORS in which the direction of the magnetic flux with respect to the coils is adjustable.

29 *d*. REACTORS or REACTANCE COILS, also called choke coils, are a form of stationary induction apparatus used to supply reactance or to produce phase displacement.

29a *e*. AN INDUCTION STARTER is a device used in starting induction motors, converters, etc., by voltage control, consisting of an auto-transformer combined with a suitable switching device.

29b A LEAKAGE REACTANCE or SERIES REACTANCE is a portion of the reactance of any induction apparatus which is due to stray or purely self-inductive flux.

D. GENERAL CLASSIFICATION OF APPARATUS.

30 COMMUTATING MACHINES. Under this head may be classed the following: Direct-current generators; direct-current motors; direct-current boosters; motor-generators; dynamotors; converters; compensators or balancers; closed-coil arc machines, and alternating-current commutating motors.

31 Commutating machines may be further classified as follows:

32 *a*. DIRECT-CURRENT COMMUTATING MACHINES, which comprise a magnetic field of constant polarity, a closed-coil armature, and a multisegmental commutator connected therewith.

33 *b*. ALTERNATING-CURRENT COMMUTATING MACHINES, which comprise a magnetic field of alternating polarity, a closed-coil armature, and a multisegmental commutator connected therewith.

34 *c*. SYNCHRONOUS COMMUTATING MACHINES, which comprise synchronous converters, motor-converters and double-current generators.

35 SYNCHRONOUS MACHINES, comprise a constant magnetic field, and an armature receiving or delivering alternating-currents in synchronism with the motion of the machine; *i.e.*, having a frequency equal to the product of the number of pairs of poles and the speed of the machine in revolutions per second.

36 STATIONARY INDUCTION APPARATUS, include transformers, auto-transformers, potential regulators, and reactors or reactance coils.

37 ROTARY INDUCTION APPARATUS, or INDUCTION MACHINES, include apparatus wherein the primary and secondary windings rotate with re-

spect to each other; *i.e.*, induction motors, induction generators, frequency converters, and rotary phase converters.

38 UNIPOLAR OR ACYCLIC MACHINES, direct-current machines, in which the voltage generated in the active conductors maintains the same direction with respect to those conductors.

39 RECTIFYING APPARATUS, PULSATING CURRENT GENERATORS.

40 ELECTROSTATIC APPARATUS, such as condensers, etc.

41 ELECTROCHEMICAL APPARATUS, such as batteries, etc.

42 ELECTROTHERMAL APPARATUS, such as heaters, etc.

42a REGULATING APPARATUS, such as rheostats, etc.

42b SWITCHING APPARATUS.

43 PROTECTIVE APPARATUS, such as fuses, circuit-breakers, lightning arresters, etc.

44 LUMINOUS SOURCES.

E. MOTORS. SPEED CLASSIFICATION.

45 MOTORS may, for convenience, be classified with reference to their speed characteristics as follows:

46 *a.* CONSTANT-SPEED MOTORS, in which the speed is either constant or does not materially vary; such as synchronous motors, induction motors with small slip, and ordinary direct-current shunt motors.

47 *b.* MULTISPEED MOTORS (two-speed, three-speed, etc.), which can be operated at any one of several distinct speeds, these speeds being practically independent of the load, such as motors with two armature windings, or induction motors with controllers for changing the number of poles.

48 *c.* ADJUSTABLE-SPEED MOTORS, in which the speed can be varied gradually over a considerable range; but when once adjusted remains practically unaffected by the load, such as shunt motors designed for a considerable range of field variation.

49 *d.* VARYING-SPEED MOTORS, or motors in which the speed varies with the load, decreasing when the load increases; such as series motors.

F. DEFINITIONS. INSTRUMENTS.

49a AN AMMETER is a current-measuring instrument, indicating in amperes.

49b A VOLTMETER is a voltage-measuring instrument, indicating in volts.

49c A WATTMETER is an instrument for measuring electrical power, and indicating in watts.

49d RECORDING AMMETERS, VOLTMETERS, WATTMETERS, etc., are instruments which record graphically upon a time-chart the values of the quantities they measure.

49e A WATT-HOUR METER is an instrument for registering total watt-hours. This term is to be preferred to the term "integrating wattmeter".

49f A VOLTMETER COMPENSATOR is a device in connection with a voltmeter, which causes the latter to indicate the voltage at some other point of the circuit.

49g A SYNCHROSCOPE is a synchronizing device which, in addition to indicating synchronism, shows whether the machine to be synchronized is fast or slow.

G. DEFINITION AND EXPLANATION OF TERMS.

(I) *LOAD FACTOR.*

50 The LOAD FACTOR of a machine, plant or system is the ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain period of time, such as a day or a year, and the maximum is taken over a short interval of the maximum load within that period.

51 In each case the interval of maximum load should be definitely specified. The proper interval is usually dependent upon local conditions and upon the purpose for which the load factor is to be determined.

(II) *DIVERSITY FACTOR.*

51a Diversity Factor is the ratio of the sum of the maximum power demands of the subdivisions of any system or part of a system, to the maximum demand of the whole system or of the part of the system under consideration, measured at the point of supply.

(III) *DEMAND FACTOR.*

51b Demand Factor is the ratio of the maximum power demand of any system or part of a system to the total connected load of the system or of the part of system under consideration.

(IV) *NON-INDUCTIVE LOAD AND INDUCTIVE LOAD.*

52 A non-inductive load is a load in which the current is in phase with the voltage across the load.

53 An inductive load is a load in which the current lags behind the voltage across the load. A load in which the current leads the voltage across the load is sometimes called a condensive or anti-inductive load.

53a When voltage and current waves are sinusoidal but not in phase, the voltage may be resolved into two components one in phase with the current, and the other in quadrature therewith. The former is called the effective component (sometimes the energy component), and the latter the reactive component of the voltage. The current may be similarly subdivided with respect to the voltage, and the two components similarly named.

(V) *POWER-FACTOR AND REACTIVE FACTOR.*

54 The Power-Factor in alternating-current circuits or apparatus is the ratio of the effective (*i.e.* the cyclic average) power in watts to the apparent power in volt-amperes. It may be expressed as follows:

$$\frac{\text{effective power}}{\text{apparent power}} = \frac{\text{effective watts}}{\text{total volt-amperes}} = \frac{\text{effective current}}{\text{total current}} = \frac{\text{effective voltage}}{\text{total voltage}}$$

55 The Reactive-Factor is the ratio of the reactive volt-amperes (*i.e.*, the product of the reactive component of current by voltage, or reactive component of voltage by current) to the total volt-amperes. It may be expressed as follows:

$$\frac{\text{reactive power}}{\text{apparent power}} = \frac{\text{reactive watts}}{\text{total volt-amperes}} = \frac{\text{reactive current}}{\text{total current}} = \frac{\text{reactive voltage}}{\text{total voltage}}$$

56 Power-Factor and Reactive-Factor are related as follows: If p = power-factor and q = reactive-factor, then with sine waves of voltage and current,

$$p^2 + q^2 = 1$$

With distorted waves of voltage and current, q ceases to have definite significance.

(VI) *SATURATION-FACTOR.*

57 The Saturation-Factor of a machine is the ratio of a small percentage increase in field excitation to the corresponding percentage increase in voltage thereby produced. The saturation factor is, therefore, a criterion of the degree of saturation attained in the magnetic circuit at any excitation selected. Unless otherwise specified, however, the saturation factor of a machine refers to the excitation existing at normal rated speed and voltage. It is determined from measurements of saturation made on open circuit at rated speed.

58 The Percentage of Saturation of a machine at any excitation may be found from its saturation curve of generated voltage as ordinates, against excitation as abscissas, by drawing a tangent to the curve at the ordinate corresponding to the assigned excitation, and extending the tangent to intercept the axis of ordinates drawn through the origin. The ratio of the intercept on this axis to the ordinate at the assigned excitation, when expressed in percentage, is the percentage of saturation and is indepen-

dent of the scale selected for excitation and voltage. This ratio is equal to the reciprocal of the saturation-factor at the same excitation, deducted from unity. Thus, if f be the saturation-factor and p the percentage of saturation,

$$p = 1 - \frac{1}{f}$$

(VII) *VARIATION AND PULSATION.*

59 The VARIATION IN PRIME MOVERS which do not give an absolutely uniform rate of rotation or speed, as in reciprocating steam engines, is the maximum angular displacement in position of the revolving member expressed in degrees, from the position it would occupy with uniform rotation, and with one revolution taken as 360 degrees.

60 The PULSATION IN PRIME MOVERS is the ratio of the difference between the maximum and minimum velocities in an engine-cycle to the average velocity.

61 The VARIATION IN ALTERNATORS or alternating-current circuits in general is the maximum difference in phase of the generated voltage wave from a wave of absolutely constant frequency of the same average value, expressed in electrical degrees (one cycle equals 360 degrees) and may be due to the variation of the prime mover.

62 The PULSATION IN ALTERNATORS or alternating-current circuits, in general, is the ratio of the difference between maximum and minimum frequency during an engine cycle to the average frequency.

63 RELATION OF VARIATION in prime mover and alternator. If p = number of pairs of poles, the variation of an alternator is p times the variation of its prime mover, if direct-connected, and $p\,n$ times the variation of the prime mover if rigidly connected thereto in the velocity ratio n; so that the speed of the alternator is n times that of the prime mover.

II. PERFORMANCE SPECIFICATIONS AND TESTS.

A. RATING.

65 RATING BY OUTPUT. All electrical apparatus should be rated by output and not by input. Generators, transformers, etc., should be rated by electrical output: motors by mechanical output, and preferably in kilowatts.

65a The following four classes of rating are recognized and recommended: they do not cover the rating of railway motors which is treated in Appendix B, and there are other large though less definitely definable classes of service in which each case must be treated by itself. Some of these may be later reduced to fairly simple terms and introduced into these Rules.

65b 1. CONTINUOUS RATING in which under load there is the attainment of approximately stationary temperature, and no other limit of capacity is exceeded.

65c 2. INTERMITTENT RATING in which one minute periods of load and rest alternate until the attainment of approximately stationary temperature and no other limit of capacity is exceeded.

65d NOTE.—Since the temperature depends upon the losses and the capacity of the apparatus to emit them, a constant load may be substituted for the intermittent load in determining the temperature, provided the losses are equivalent.

65e 3. MINUTE RATING in which under load for one minute, no mechanical, thermal, magnetic, or electrical limit of capacity is exceeded and no permanent change is wrought in the apparatus.

65f 4. VARIABLE SERVICE RATING. It is desirable here to recognize this class of rating which is intended to cover the rating of motors for machine-tool and similar service, in which the thermal absorptive capacity plays a part. The specifications for this rating have not been fully determined at the time that this edition of the Rules goes to press.

66 RATING IN KILOWATTS. Electrical power should be expressed in kilowatts, except when otherwise specified.

67 APPARENT POWER, KILOVOLT-AMPERES. Apparent power in alternating-current circuits should be expressed in kilovolt-amperes as distinguished from effective power in kilowatts. When the power factor is 100 per cent, the apparent power in kilovolt-amperes is equal to the kilowatts.

68 The RATED (FULL-LOAD) CURRENT is that current which, with the rated terminal voltage, gives the rated kilowatts, or the rated kilovolt-amperes. In machines in which the rated voltage differs from the no-load voltage, the rated current should refer to the former.

69 DETERMINATION OF RATED CURRENT. The rated current may be determined as follows: If P = rating in watts, or volt-amperes if the power factor be other than 100 per cent, and E = full-load terminal voltage, the rated current per terminal is:

70 $I = \frac{P}{E}$ amperes, in a direct-current machine or single-phase alternator.

71 $I = \frac{1}{\sqrt{3}} \frac{P}{E}$ amperes, in a three-phase alternator.

72 $I = \frac{1}{2} \frac{P}{E}$ amperes, in a quarter-phase alternator.

73 NORMAL CONDITIONS. The rating of machines or apparatus should be based upon certain normal conditions to be assumed as standard, or to be specified. These conditions include voltage, current, power-factor, frequency, wave shape and speed; or such of them as may apply in each particular case. Performance tests should be made under these standard conditions unless otherwise specified.

74 *a*. POWER FACTOR. Since the inherent capacity of alternating current generators, synchronous motors, and transformers, depends upon their voltage and their current, they should be rated in kilovolt-amperes If the apparatus is rated in kilowatts without specification as to the power factor, a power factor of 100 per cent shall be understood.

If rated in kilowatts and a power factor other than 100 per cent be specified, this should be understood as defining only the nature of the load, and not as implying an increase in the ampere rating of the apparatus, which should be based upon the kilowatt rating at 100 per cent power factor.

75 *b*. WAVE SHAPE. In determining the rating of alternating-current machines or apparatus, a sine wave shape of alternating current and voltage is assumed, except where a distorted wave shape is inherent to the apparatus. See Secs. 79–80.

76 FUSES. The rating of a fuse should be the maximum current which it will continuously carry.

77 CIRCUIT-BREAKERS. The rating of a circuit-breaker should be the maximum current which it is designed to carry continuously.

77a NOTE. In addition thereto, the maximum current and voltage at which a fuse or a circuit-breaker will open the circuit should be specified. It is to be noted that the behavior of fuses and of circuit-breakers is much influenced by the amount of electric power available on the circuit.

78 INDICATING METERS should be rated according to their full-scale reading of volts, amperes, or watts. In wattmeters the rated volts and rated amperes should also be included; *i.e.*, the volts and amperes which can be safely and continuously carried by the voltage and current coils respectively.

78a WATT-HOUR METERS should be rated in volts and amperes.

B. WAVE SHAPE.

79 The SINE WAVE should be considered as standard, except where a deviation therefrom is inherent in the operation of the apparatus

80 A MAXIMUM DEVIATION of the wave from sinusoidal shape not exceeding 10 per cent is permissible, except when otherwise specified. See Section 5j.

81, 82, 83. See Sections 5e to 5l.

C. EFFICIENCY.

(I) *DEFINITIONS.*

84 The EFFICIENCY of an apparatus is the ratio of its output to its input. The output and input may be in terms of watt-hours, watts, volt-amperes, amperes, or any other quantity of interest, thus respectively defining energy-efficiency, power-efficiency, apparent-power-efficiency, current-efficiency, etc. Unless otherwise specified, however, the term is ordinarily assumed to refer to power-efficiency. An exception should be noted in the case of luminous sources, (see Sec. 346).

86 APPARENT EFFICIENCY. In apparatus in which a phase displacement is inherent to their operation, apparent efficiency should be understood as the ratio of net power output to volt-ampere input.

87 *a.* NOTE. Such apparatus comprises induction motors, synchronous phase modifiers, synchronous converters controlling the voltage of an alternating-current system, potential regulators, open magnetic circuit transformers, etc.

88 *b.* NOTE. Since the apparent efficiency of apparatus delivering electric power depends upon the power-factor of the load, the apparent efficiency, unless otherwise specified, should be referred to a load power-factor of unity.

(II) *MEASUREMENT OF EFFICIENCY.*

89 METHODS. Efficiency may be determined by either of two methods, *viz.*: by measurement of input and output; or, by measurement of losses.

90 *a.* METHOD OF INPUT AND OUTPUT. The input and output may both be measured directly. The ratio of the latter to the former is the efficiency.

91 *b.* METHOD BY LOSSES. The losses may be measured either collectively or individually. The total losses may be added to the output to derive the input, or subtracted from the input to derive the output.

92 COMPARISON OF METHODS. The output and input method is preferable with small machines. When, however, as in the case of large machines, it is impracticable to measure the output and input; or when the percentage of power loss is small and the efficiency is nearly unity, the method of determining efficiency by measuring the losses should be followed.

93 ELECTRIC POWER should be measured at the terminals of the apparatus. In tests of polyphase machines, the measurement of power should not be confined to a single circuit but should be extended to all the circuits in order to avoid errors of unbalanced loading.

94 MECHANICAL POWER in machines should be measured at the pulley, gearing, coupling, etc., thus excluding the loss of power in said pulley, gearing or coupling, but including the bearing friction and windage. The magnitude of bearing friction and windage may be considered, with constant speed, as independent of the load. The loss of power in the belt and the increase of bearing friction due to belt tension should be excluded. Where, however, a machine is mounted upon the shaft of a prime mover, in such a manner that it cannot be separated therefrom, the frictional losses in bearings and in windage, which ought, by definition, to be included in determining the efficiency, should be excluded, owing to the practical impossibility of separating them from those of the prime mover.

95 In AUXILIARY APPARATUS, such as an exciter, the power lost in the auxiliary apparatus should not be charged to the principal machine, but to the plant consisting of principal machine and auxiliary apparatus taken together. The plant efficiency in such cases should be distinguished from the machine efficiency.

96 NORMAL CONDITIONS. Efficiency tests should be made under normal conditions herein set forth, which are to be assumed as standard. These conditions include voltage, current, power-factor, frequency, wave shape, speed, temperature and barometric pressure, or such of them as may apply in each particular case. Performance tests should be made under these standard conditions unless otherwise specified. See Secs. 73–75.

97 *a.* TEMPERATURE. The efficiency of all apparatus, except such as may be intended for intermittent service should be either measured at, or re-

duced to, the temperature which the apparatus assumes under continuous operation at rated load, referred to a room temperature of 25 deg. cent. See Secs. 267–292.

98 With apparatus intended for intermittent service, the efficiency should be determined at the temperature assumed under specified conditions.

99 *b.* Power Factor. In determining the efficiency of alternating-current apparatus, the electric power should be measured when the current is in phase with the voltage, unless otherwise specified, except when a definite phase difference is inherent in the apparatus, as in induction motors, induction generators, frequency converters, etc.

100 *c.* Wave Shape. In determining the efficiency of alternating-current apparatus, the sine wave should be considered as standard, except where a difference in the wave form from the sinusoidal is inherent in the operation of the apparatus. See Sec. 80.

(III) *MEASUREMENT OF LOSSES.*

101 Losses. The usual sources of losses in electrical apparatus and the methods of determining these losses are as follows:

102 (*A*) Bearing Friction and Windage.

The magnitude of bearing friction and windage (which may be considered as independent of the load) is conveniently measured by driving the machine from an independent motor, the output of which may be suitably determined. See Sec. 94.

(*B*) Commutator Brush Friction.

103 The magnitude of the commutator brush friction (which may be considered as independent of the load) is determined by measuring the difference in power required for driving the machine with brushes on and with brushes off (the field being unexcited).

(*C*) Collector-Ring Brush Friction.

104 Collector-ring brush friction may be determined in the same manner as commutator brush friction. It is usually negligible.

(*D*) Molecular Magnetic Friction and Eddy Currents.

105 These losses include those due to molecular magnetic friction and eddy currents in iron and copper and other metallic parts, also the losses due to currents in the cross-connections of cross-connected armatures.

106 In Machines these losses should be determined on open circuit and at a voltage equal to the rated voltage $+I\,r$ in a generator, and $-I\,r$ in a motor, where I denotes the current strength and r denotes the internal resistance of the machine. They should be measured at the correct speed and voltage, since they do not usually vary in any definite proportion to the speed or to the voltage.

107 Note. The Total Losses in bearing friction and windage, brush friction, magnetic friction and eddy currents can, in general, be determined by a single measurement by driving the machine with the field excited, either as a motor, or by means of an independent motor.

108 Retardation Method. The no-load iron, friction, and windage losses may be segregated by the Retardation Method. The generator should be brought up to full speed (or, if possible, to about 10 per cent above full speed) as a motor, and, after cutting off the driving power and excitation, frequent readings should be taken of speed and time, as the machine slows down, from which a speed-time curve can be plotted. A second curve should be taken in the same manner, but with full field excitation; from the second curve the iron losses may be found by subtracting the losses found in the first curve.

109 The speed-time curves can be plotted automatically by belting a small separately excited generator (say 1/10 kw.) to the generator shaft and connecting it to a recording voltmeter.

(*E*) Armature-Resistance Loss.

110 This loss may be expressed by $p\,I^2\,r$; where r = resistance of one armature circuit or branch, I = the current in such armature circuit or branch, and p = the number of armature circuits or branches.

(*F*) COMMUTATOR, BRUSH AND BRUSH-CONTACT RESISTANCE LOSS.

111 It is desirable to point out that with carbon brushes these losses may be considerable in low-voltage machines.

(*G*) COLLECTOR-RING AND BRUSH-CONTACT RESISTANCE LOSS.

112 This loss is usually negligible, except in machines of extremely low voltage or in unipolar machines.

(*H*) FIELD-EXCITATION LOSS.

113 With separately excited field, the loss of power in the resistance of the field coils alone should be considered. With either shunt- or series-field windings, however, the loss of power in the accompanying rheostat should also be included, the said rheostat being considered as an essential part of the machine, and not as separate auxiliary apparatus.

114 (*I*) LOAD LOSSES.

The load losses may be considered as the difference between the total losses under load and the sum of the losses as above specified and determined.

115 *a.* In COMMUTATING MACHINES of small field distortion, the load losses are usually trivial and may, therefore, be neglected. When, however, the field distortion is large as in commutating-pole machines, or, as is shown, for instance, by the necessity for shifting the brushes between no load and full load on non-commutating pole machines, these load losses may be considerable, and should be taken into account. In this case the efficiency may be determined either by input and output measurements, or the load losses may be estimated by the method of Sec. 116.

116 *b.* ESTIMATION OF LOAD LOSSES. While the load losses cannot well be determined individually, they may be considerable and, therefore, their joint influence should be determined by observation. This can be done by operating the machine on short-circuit and at full-load current, that is, by determining what may be called the "short-circuit core loss." With the low field intensity and great lag of current existing in this case, the load losses are usually greatly exaggerated.

117 One-third of the short-circuit core loss may, as an approximation, and in the absence of more accurate information, be assumed as the load loss.

(IV) *EFFICIENCY OF DIFFERENT TYPES OF APPARATUS*

(*A*) DIRECT-CURRENT COMMUTATING MACHINES.

118 In DIRECT-CURRENT COMMUTATING MACHINES the losses are:

119 *a.* BEARING FRICTION AND WINDAGE. See Measurement of Losses (*A*), Sec. 102.

120 *b.* MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of Losses (*D*), Sec. 105.

121 *c.* ARMATURE RESISTANCE LOSSES. See Measurement of Losses (*E*), Sec. 110.

122 *d.* COMMUTATOR BRUSH FRICTION. See Measurement of Losses (*B*), Sec. 103.

123 *e.* COMMUTATOR, BRUSH AND BRUSH-CONTACT RESISTANCE. See Measurement of Losses (*F*), Sec. 111.

124 *f.* FIELD EXCITATION LOSS. See Measurement of Losses (*H*), Sec. 113.

125 *g.* LOAD LOSSES. See Measurement of Losses (*I*), Sec. 114.

126 NOTE. *b* and *c* are losses in the armature or "armature losses"; *d* and *e* "commutator losses"; *f* "field losses."

(*B*) ALTERNATING-CURRENT COMMUTATING MACHINES.

127 In ALTERNATING-CURRENT COMMUTATING MACHINES, the losses are:

128 *a.* BEARING FRICTION AND WINDAGE. See Measurement of Losses (*A*), Sec. 102.

129 *b.* ROTATION LOSS, measured with the machine at open circuit, the brushes on the commutator, and the field excited by alternating current when driving the machine by a motor.

130 This loss includes molecular magnetic friction and eddy currents, caused by rotation through the magnetic field, $I^2 r$ losses in cross-con-

nections of cross-connected armatures, I^2r and other losses in armature-coils and armature-leads which are short-circuited by the brushes as far as these losses are due to rotation.

131 *c*. ALTERNATING OR TRANSFORMER LOSS. These losses are measured by wattmeter in the field circuit, under the conditions of test *b*. They include molecular magnetic friction and eddy-currents due to the alternation of the magnetic field, I^2r losses in cross-connections of cross-connected armatures, I^2r and other losses in armature coil and commutator leads which are short-circuited by the brushes, as far as these losses are due to the alternation of the magnetic flux.

132 The losses in armature-coils and commutator leads short-circuited by the brushes, can be separated in *b*, and *c*, from the other losses, by running the machine with and without brushes on the commutator.

133 *d*. I^2R Loss, other load losses in armature and compensating winding and I^2r loss of brushes, may be measured by a wattmeter connected across the armature and compensating winding.

134 *e*. FIELD EXCITATION LOSS. See Measurement of Losses (*H*), Sec. 113.

135 *f*. COMMUTATOR BRUSH-FRICTION. See Measurement of Losses (*B*), Sec. 103.

(*C*) SYNCHRONOUS COMMUTATING MACHINES.

136 1. In DOUBLE-CURRENT GENERATORS, the efficiency of the machine should be determined as a direct-current generator, and also as an alternating-current generator. The two values of efficiency may be different, and should be clearly distinguished.

137 2. In CONVERTERS the losses should be determined when driving the machine by a motor. These losses are:

138 *a*. BEARING FRICTION AND WINDAGE. See Measurement of Losses (*A*), Sec. 102.

139 *b*. MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of losses (*D*) Sec. 105.

140 *c*. ARMATURE-RESISTANCE LOSS. This loss in the armature is $q\,I^2r$, where I = direct current in armature, r = armature resistance and q. a factor which is equal to 1.47 in single-circuit single-phase, 1.15 in double-circuit single-phase, 0.59 in three-phase, 0.39 in two-phase, and 0.27 in six-phase converters.

141 *d*. COMMUTATOR-BRUSH FRICTION. See Measurement of Losses (*B*), Sec. 103.

142 *e*. COLLECTOR-RING BRUSH FRICTION. See Measurement of Losses (*C*), Sec. 104.

143 *f*. COMMUTATOR, BRUSH AND BRUSH-CONTACT RESISTANCE LOSS. See Measurement of Losses (*F*) Sec. 111.

144 *g*. COLLECTOR-RING BRUSH-CONTACT RESISTANCE LOSS. See Measurement of Losses (*G*), Sec. 112.

145 *h*. FIELD-EXCITATION LOSS. See Measurement of Losses (*H*), Sec. 109.

146 *i*. LOAD LOSSES. These can generally be neglected, owing to the absence of field distortion.

147 3. THE EFFICIENCY OF TWO SIMILAR CONVERTERS may be determined by operating one machine as a converter from direct to alternating, and the other as a converter from alternating to direct, connecting the alternating sides together, and measuring the difference between the direct-current input and the direct-current output. This process may be modified by returning the output of the second machine through two boosters into the first machine and measuring the losses. Another modification is to supply the losses by an alternator between the two machines, using potential regulators.

(*D*) SYNCHRONOUS MACHINES.

148 In SYNCHRONOUS MACHINES the losses are:

149 *a*. BEARING FRICTION AND WINDAGE. See Measurement of Losses (*A*), Sec. 102.

150 *b*. MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of Losses (*D*), Sec. 105.

151 *c.* ARMATURE-RESISTANCE LOSS. See Measurement of Losses (*E*), Sec. 110.

152 *d.* COLLECTOR-RING BRUSH FRICTION. See Measurement of Losses (*C*), Sec. 104.

153 *e.* COLLECTOR-RING BRUSH-CONTACT RESISTANCE LOSS. See Measurement of Losses (*G*), Sec. 112.

154 *f.* FIELD-EXCITATION LOSS. See Measurement of Losses (*H*), Sec. 113.

155 *g.* LOAD LOSSES. See Measurement of Losses (*I*), Sec. 114.

(*E*) STATIONARY INDUCTION APPARATUS.

156 In STATIONARY INDUCTION APPARATUS, the losses are:

157 *a.* MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS measured at open secondary circuit, rated frequency, and at rated voltage $-I\ r$, where I = rated current, r = resistance of primary circuit.

158 *b.* RESISTANCE LOSSES, the sum of the $I^2\ r$ losses in the primary and in the secondary windings of a transformer, or in the two sections of the coil in a compensator or auto-transformer, where I = rated current in the coil or section of coil, and r = resistance.

159 *c.* LOAD LOSSES, *i.e.*, eddy currents in the iron and especially in the copper conductors, caused by the current at rated load. For practical purposes they may be determined by short-circuiting the secondary of the transformer and impressing upon the primary a voltage sufficient to send rated load current through the transformer. The loss in the transformer under these conditions, measured by wattmeter, gives the load losses $+ I^2\ r$ losses in both primary and secondary coils.

160 In CLOSED MAGNETIC CIRCUIT TRANSFORMERS, either of the two circuits may be used as primary when determining the efficiency.

161 In POTENTIAL REGULATORS, the efficiency should be taken at the maximum voltage for which the apparatus is designed, and with non-inductive load, unless otherwise specified.

(*F*) ROTARY INDUCTION APPARATUS, OR INDUCTION MACHINES

162 In ROTARY INDUCTION APPARATUS, the losses are:

163 *a.* BEARING FRICTION AND WINDAGE. See Measurement of Losses (*A*), Sec. 102.

164 *b.* MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS in iron, copper and other metallic parts; also $I^2\ r$ losses which may exist in multiple-circuit windings. *a* and *b* together are determined by running the motor without load at rated voltage, and measuring the power input.

165 *c.* PRIMARY $I^2\ R$ LOSS, which may be determined by measurement of the current and the resistance.

166 *d.* SECONDARY $I^2\ R$ LOSS, which may be determined as in the primary, when feasible; otherwise, as in squirrel-cage secondaries, this loss is measured as part of *e*.

167 *e.* LOAD LOSSES; *i.e.*, molecular magnetic friction, and eddy currents in iron, copper, etc., caused by the stray field of primary and secondary currents, and secondary $I^2\ R$ loss when undeterminable under (*d*). These losses may for practical purposes be determined by measuring the total power, with the rotor short-circuited at standstill and a current in the primary circuit equal to the primary energy current at full load. The loss in the motor under these conditions may be assumed to be equal to the load losses $+ I^2\ r$ losses in both primary and secondary coils.

(*G*) UNIPOLAR OR ACYCLIC MACHINES.

168 In UNIPOLAR MACHINES, the losses are:

169 (*a*) BEARING FRICTION AND WINDAGE. See Measurement of Losses (*A*), Sec. 102.

170 (*b*) MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of Losses (*E*), Sec. 108.

171 (*c*) ARMATURE-RESISTANCE LOSSES. See Measurement of Losses (*E*), Sec. 110.

172 (*d*) COLLECTOR-BRUSH FRICTION. See Measurement of Losses (*C*), Sec. 104.

173 (*e*) COLLECTOR BRUSH-CONTACT RESISTANCE. See Measurement of Losses (*G*), Sec. 112.

174 (*f*) FIELD-EXCITATION. See Measurement of Losses (*H*), Sec. 113.

175 (*g*) LOAD LOSSES. See Measurement of Losses (*I*), Sec. 114.

(*H*) RECTIFYING APPARATUS, PULSATING-CURRENT GENERATORS.

176 This division includes: open-coil arc machines and mechanical and other rectifiers.

177 In RECTIFIERS the most satisfactory method of determining the efficiency is to measure both electric input and electric output by wattmeter. The input is usually inductive, owing to phase displacement and to wave distortion. For this reason the power factor and the apparent efficiency should also be considered, since the latter may be much lower than the true efficiency. The power consumed by auxiliary devices, such as the synchronous motor or cooling devices, should be included in the electric input.

178 In CONSTANT-CURRENT RECTIFIERS, transforming from constant potential alternating to constant direct current, by means of constant-current transforming devices and rectifying devices, the losses in the transforming devices are to be included in determining the efficiency and have to be measured when operating the rectifier, since in this case the losses may be greater than when feeding an alternating secondary circuit. In constant-current transforming devices, the load losses may be considerable, and therefore, should not be neglected.

179 In OPEN-COIL ARC MACHINES, the losses are essentially the same as in direct-current (closed coil) commutating machines. In this case, however, the load losses are usually greater, and the efficiency should preferably be measured by input- and output-test, using wattmeters for measuring the output.

179a In alternating-current rectifiers, the output should, in general, be measured by wattmeter and not by voltmeter and ammeter, since owing to pulsation of current and voltage, a considerable discrepancy may exist between watts and volt-amperes. If, however, a direct-current and an alternating-current meter in the rectified circuit (either a voltmeter or an ammeter) give the same reading, the output may be measured by direct-current voltmeter and ammeter. The type of alternating-current instrument here referred to should indicate the effective or root-of-mean-square value and the type of direct-current instrument the arithmetical mean value, which would be zero on an alternating-current circuit.

(*I*) TRANSMISSION LINES.

180 The EFFICIENCY of transmission lines should be measured with non-inductive load at the receiving end, with the rated receiving voltage and frequency, also with sinusoidal impressed wave form, except where expressly specified otherwise, and with the exclusion of transformers or other apparatus at the ends of the line.

(*J*) PHASE-DISPLACING APPARATUS.

183 In SYNCHRONOUS PHASE-MODIFIERS and exciters of induction generators, the determination of losses is the same as in other synchronous machines.

184 In REACTORS the losses are molecular magnetic friction, eddy losses and $I^2 r$ loss. They should be measured by wattmeter. The losses of reactors should be determined with a sine wave of impressed voltage except where expressly specified otherwise.

185 In CONDENSERS, the losses are due to dielectric hysteresis and leakage, and should be determined by wattmeter with a sine wave of voltage or by an alternating-current bridge method.

186 In POLARIZATION CELLS, the losses are those due to electric resistivity and a loss in the electrolyte of the nature of chemical hysteresis. These losses may be considerable. They depend upon the frequency, voltage and temperature, and should be determined with a sine wave of impressed voltage, except where expressly specified otherwise.

D. REGULATION.

(I) *DEFINITIONS.*

187 The REGULATION of a machine or apparatus in regard to some characteristic quantity (such as terminal voltage, current or speed) is the ratio of the deviation of that quantity from its normal value at rated load to that normal value. The term "regulation," therefore, has the same meaning as the term "inherent regulation," occasionally used.

188 CONSTANT STANDARD. If the characteristic quantity is intended to remain constant (*e.g.*, constant voltage, constant speed, etc.) between rated load and no load, the regulation is the ratio of the maximum variation from the rated-load value to the no-load value.

189 VARYING STANDARD. If the characteristic quantity is intended to vary in a definite manner between rated load and no load, the regulation is the ratio of the maximum variation from the specified condition to the normal rated-load value.

190 (*a*) NOTE. If the law of the variation (in voltage, current, speed, etc.) between rated load and no load is not specified, it should be assumed to be a simple linear relation; *i.e.*, one undergoing uniform variation between rated load and no load.

191 (*b*) NOTE. The regulation of an apparatus may, therefore differ according to its qualification for use. Thus, the regulation of a compound-wound generator specified as a constant-potential generator, will be different from that which it possesses when specified as an over-compounded generator.

192 In CONSTANT-POTENTIAL MACHINES, the regulation is the ratio of the maximum difference of terminal voltage from the rated-load value (occurring within the range from rated load to open circuit) to the rated load terminal voltage.

193 In CONSTANT-CURRENT MACHINES, the regulation is the ratio of the maximum difference of current from the rated-load value (occurring within the range from rated-load to short-circuit, or minimum limit of operation), to the rated-load current.

194 In CONSTANT-POWER APPARATUS, the regulation is the ratio of maximum difference of power from the rated load value (occurring within the range of operation specified) to the rated power.

195 In CONSTANT-SPEED DIRECT-CURRENT MOTORS and INDUCTION MOTORS the regulation is the ratio of the maximum variation of speed from its rated load value (occurring within the range from rated load to no-load) to the rated load speed.

196 The regulation of an induction motor is, therefore, not identical with the slip of the motor, which is the ratio of the drop in speed from synchronism, to the synchronous speed.

197 In CONSTANT-POTENTIAL TRANSFORMERS, the regulation is the ratio of the rise of secondary terminal voltage from rated non-inductive load to no-load (at constant primary impressed terminal voltage) to the secondary terminal voltage at rated load.

198 In OVER-COMPOUNDED MACHINES, the regulation is the ratio of the maximum difference in voltage from a straight line connecting the no-load and rated-load values of terminal voltage as function of the load current, to the rated-load terminal voltage.

199 In CONVERTERS, DYNAMOTORS, MOTOR-GENERATORS AND FREQUENCY CONVERTERS, the regulation is the ratio of the maximum difference of terminal voltage at the output side from the rated-load voltage, to the rated-load voltage on the output side.

200 In TRANSMISSION LINES, FEEDERS, ETC., the regulation is the ratio of the maximum voltage difference at the receiving end, between rated non-inductive load and no load to the rated-load voltage at the receiving end (with constant voltage impressed upon the sending end).

201 In STEAM ENGINES, the regulation is the ratio of the maximum variation of speed in passing slowly from rated-load to no-load (with constant steam pressure at the throttle) to the rated-load speed. For variation and pulsation see Secs. 59–64.

202 In a HYDRAULIC TURBINE or OTHER WATER-MOTOR, the regulation is the ratio of the maximum variation of speed in passing slowly from rated-load to no-load (at constant head of water; *i.e.*, at constant difference of level between tail race and head race), to the rated-load speed. For variation and pulsation see Secs. 59–64.

203 In a GENERATOR-UNIT, consisting of a generator united with a prime-mover, the regulation should be determined at constant conditions of the prime-mover; *i.e.*, constant steam pressure, head, etc. It includes the inherent speed variations of the prime-mover. For this reason the regulation of a generator-unit is to be distinguished from the regulation of either the prime-mover, or of the generator contained in it, when taken separately.

(II) *CONDITIONS FOR AND TESTS OF REGULATION.*

204 SPEED. The REGULATION OF GENERATORS is to be determined at constant speed, and of alternating apparatus at constant impressed frequency.

205 NON-INDUCTIVE LOAD. In apparatus generating, transforming or transmitting alternating currents, regulation should be understood to refer to non-inductive load, that is, to a load in which the current is in phase with the e.m.f. at the output side of the apparatus, except where expressly specified otherwise.

206 WAVE FORM. In alternating apparatus receiving electric power, regulation should refer to a sine wave of e.m.f., except where expressly specified otherwise.

207 EXCITATION. In commutating machines, rectifying machines, and synchronous machines, such as direct-current generators and motors, alternating-current and polyphase generators, the regulation is to be determined under the following conditions:

(1) At constant excitation in separately excited fields.

(2) With constant resistance in shunt-field circuits, and

(3) With constant resistance shunting series-field circuits; *i.e.*, the field adjustment should remain constant, and should be so chosen as to give the required rated-load voltage at rated-load current.

208 IMPEDANCE RATIO. In alternating-current apparatus, in addition to the non-inductive regulation, the impedance ratio of the apparatus should be specified; *i.e.*, the ratio of the voltage consumed by the total internal impedance of the apparatus at rated-load current, to its rated-load voltage. As far as possible, a sinusoidal current should be used.

209 COMPUTATION OF REGULATION. In synchronous machines the open-circuit exciting ampere-turns corresponding to terminal voltage plus armature-resistance-drop, and the exciting ampere-turns at short-circuit for rated-load current should be combined vectorially to obtain the resultant ampere-turns, and the corresponding internal e.m.f. should be taken from the saturation curve.

E. INSULATION.

(I) *INSULATION RESISTANCE.*

210 INSULATION RESISTANCE is the ohmic resistance offered by an insulating coating, cover, material or support to an impressed voltage, tending to produce a leakage of current through the same.

211 OHMIC RESISTANCE AND DIELECTRIC STRENGTH. The ohmic resistance of the insulation is of secondary importance only, as compared with the dielectric strength, or resistance to rupture by high voltage. Since the ohmic resistance of the insulation can be very greatly increased by baking, but the dielectric strength is liable to be weakened thereby, it is preferable to specify a high dielectric strength rather than a high insulation resistance. The high-voltage test for dielectric strength should always be applied.

212 RECOMMENDED VALUE OF RESISTANCE. The insulation resistance of completed apparatus should be such that the rated terminal voltage of the apparatus will not send more than $\frac{1}{1,000,000}$ of the rated-load current,

through the insulation. Where the value found in this way exceeds one megohm, it is usually sufficient.

213 INSULATION RESISTANCE TESTS should, if possible, be made at the pressure for which the apparatus is designed.

(II) *DIELECTRIC STRENGTH.*

(*A*) TEST VOLTAGES.

214 DEFINITION. The dielectric strength of an insulating wall, coating, cover or path is measured by the voltage which must be applied to it in order to effect a disruptive discharge through the same.

215 BASIS FOR DETERMINING TEST VOLTAGES. The test voltage which should be applied to determine the suitability of insulation for commercial operation is dependent upon the kind and size of the apparatus and its normal operating voltage, upon the nature of the service in which it is to be used, and the severity of the mechanical and electrical stresses to which it may be subjected. The voltages and other conditions of test which are recommended have been determined as reasonable and proper for the great majority of cases and are proposed for general adoption, except when specific reasons make a modification desirable.

216 CONDITION OF APPARATUS TO BE TESTED. Commercial tests should, in general, be made with the completely assembled apparatus and not with individual parts. The apparatus should be in good condition and high-voltage tests, unless otherwise specified, should be applied before the machine is put into commercial service, and should not be applied when the insulation resistance is low owing to dirt or moisture. High-voltage tests should, in general, be made at the temperature assumed under normal operation. High-voltage tests considerably in excess of the normal voltages to determine whether specifications are fulfilled are admissable on new machines only. Unless otherwise agreed upon, high-voltage tests of a machine should be understood as being made at the factory.

217 POINTS OF APPLICATION OF VOLTAGE. The test voltage should be successively applied between each electric circuit and all other electric circuits including conducting material in the apparatus.

218 The FREQUENCY of the alternating-current test voltage is, in general, immaterial within commercial ranges. When, however, the frequency has an appreciable effect, as in alternating-current apparatus of high voltage and considerable capacity, the rated frequency of the apparatus should be used.

219 TABLE OF TESTING VOLTAGES. The following voltages are recommended for testing all apparatus, lines and cables, by a continued application for one minute. The test should be with alternating voltage having a virtual value (or root mean square referred to a sine wave of voltage) given in the table, and preferably for tests of alternating apparatus at the normal frequency of the apparatus.

220

Rated Terminal Voltage of Circuit.	Rated Output.	Testing Voltage
Not exceeding 400 volts	Under 10 kw.	1,000 volts
" " "	10 kw. and over	1,500 "
400 and over, but less than 800 volts	Under 10 kw.	1,500 "
" " " " "	10 kw. and over	2,000 "
800 " " " 1,200 "	Any	3,500 "
1,200 " " " 2,500 "	Any	5,000 "
2,500 " "	Any.	Double the normal rated voltages.

221 EXCEPTION.—TRANSFORMERS. Transformers having primary pressures of from 550 to 5,000 volts, the secondaries of which are directly connected to consumption circuits, should have a testing voltage of 10,000 volts, to be applied between the primary and secondary windings, and also between the primary winding and the core.

222 EXCEPTION.—FIELD WINDINGS. The tests for field windings should be based on the rated voltage of the exciter and the rated output of the machine of which the coils are a part. Field windings of synchronous motors and converters, which are to be started by applying alternating current to the armature when the field is not excited and when a high voltage is induced in the field windings, should be tested at 5,000 volts.

223 RATED TERMINAL VOLTAGE.—DEFINITION. The rated terminal voltage of circuit in the above table, means the voltage between the conductors of the circuit to which the apparatus to be tested is to be connected,—for instance, in three-phase circuits the delta voltage should be taken. In the following specific cases, the rated terminal voltage of the circuit is to be determined as specified in ascertaining the testing voltage:

224 (*a*) TRANSFORMERS. The test of the insulation between the primary and secondary windings of transformers, is to be the same as that between the high-voltage windings and core, and both tests should be made simultaneously by connecting the low-voltage winding and core together during the test. If a voltage equal to the specified testing voltage be induced in the high-voltage winding of a transformer it may be used for insulation tests instead of an independently induced voltage. These tests should be made first with one end and then with the other end of the high-tension winding connected to the low-tension winding and to the core.

225 (*b*) CONSTANT-CURRENT APPARATUS. The testing voltage is to be based upon a rated terminal voltage equal to the maximum voltage which may exist at open or closed circuit.

226 (*c*) APPARATUS IN SERIES. For tests of machines or apparatus to be operated in series, so as to employ the sum of their separate voltages the testing voltage is to be based upon a rated terminal voltage equal to the sum of the separate voltages except where the frames of the machines are separately insulated, both from the ground and from each other, in which case the test for insulation between machines should be based upon the voltage of one machine, and the test between each machine and ground to be based upon the total voltage of the series.

(*B*) METHODS OF TESTING.

227 CLASSES OF TESTS. Tests for dielectric strength cover such a wide range in voltage that the apparatus, methods and precautions which are essential in certain cases do not apply to others. For convenience, the tests will be separated into two classes:

228 CLASS 1. This class includes all apparatus for which the test voltage does not exceed 10 kilovolts, unless the apparatus is of very large static capacity, *e.g.*, a large cable system. This class also includes all apparatus of small static capacity, such as line insulators, switches and the like, for all test voltages.

229 METHOD OF TEST FOR CLASS 1. The test voltage is to be continuously applied for the prescribed interval,—(one minute unless otherwise specified). The test voltage may be taken from a constant-potential source and applied directly to the apparatus to be tested, or it may be raised gradually as specified for tests under Class 2.

230 CLASS 2. This class includes all apparatus not included in Class 1.

231 METHOD OF TEST FOR CLASS 2. The test voltage is to be raised to the required value smoothly and without sudden large increments and is then to be continuously applied for the prescribed interval,—(one minute, unless otherwise specified), and then gradually decreased.

232 CONDITIONS AND PRECAUTIONS FOR CLASS 1 and CLASS 2. The following apply to all tests:

233 The WAVE SHAPE should be approximately sinusoidal and the apparatus in the testing circuits should not materially distort this wave.

234 The SUPPLY CIRCUIT should have ample current-supply capacity so that the charging current which may be taken by the apparatus under test will not materially alter the wave form nor materially affect the test voltage. The circuit should be free from accidental interruptions.

235 RESISTANCE OR INDUCTANCE in series with the primary of a raising transformer for the purpose of controlling its voltage is liable seriously to affect the wave form, thereby causing the maximum value of the voltage to bear a different and unknown ratio to the root mean square value. This method of voltage adjustment is, therefore, in general, undesirable. It may be noted that if a resistance or inductance is employed to limit the current when burning out a fault, such resistance or inductance should be short circuited during the regular voltage test.

236 The INSULATION under test should be in normal condition as to dryness and the temperature should when possible be that reached in normal service.

237 ADDITIONAL CONDITIONS AND PRECAUTIONS FOR CLASS 2. The following conditions and precautions, in addition to the foregoing, apply to tests of apparatus included in Class 2.

238 SUDDEN INCREMENT OF TESTING VOLTAGE on the apparatus under test should be avoided, particularly at high voltages and with apparatus having considerable capacity, as a momentarily excessive rise in testing voltage will result.

239 SUDDEN VARIATIONS IN TESTING VOLTAGE of the circuit supplying the voltage during the test should be avoided as they are likely to set up injurious oscillation.

240 GOOD CONNECTIONS in the circuits supplying the test voltage are essential in order to prevent injurious high frequency disturbances from being set up. When a heavy current is carried by a small water rheostat, arcing may occur, causing high-frequency disturbances which should be carefully avoided.

241 TRANSFORMER COILS. In high-voltage transformers, the low-voltage coil should preferably be connected to the core and to the ground when the high-voltage test is being made, in order to avoid the stress from low-voltage coil to core, which would otherwise result through condenser action. The various terminals of each winding of the high-tension transformer under test should be connected together during the test in order to prevent undue stress on the insulation between turns or sections of the winding in case the high-voltage test causes a break-down.

(*C*) METHODS FOR MEASURING THE TEST VOLTAGE.

242 FOR MEASURING THE TEST VOLTAGE, two instruments are in common use, (1) the spark gap and (2) the voltmeter.

243 1. THE SPARK GAP is ordinarily adjusted so that it will break down with a certain predetermined voltage, and is connected in parallel with the insulation under test. It ensures that the voltage applied to the insulation is not greater than the break-down voltage of the spark gap. A given setting of the spark gap is a measure of one definite voltage, and, as its operation depends upon the maximum value of the voltage wave, it is independent of wave form and is a limit on the maximum stress to which the insulation is subjected. The spark gap is not conveniently adapted for comparatively low voltages.

244 In SPARK-GAP MEASUREMENTS, the spark gap may be set for the required voltage and the auxiliary apparatus adjusted to give a voltage at which this spark gap just breaks down. The spark gap should then be adjusted for, say, 10 per cent higher voltage, and the auxiliary apparatus again adjusted to give the voltage of the former breakdown, which is to be the assumed voltage for the test. This voltage is to be maintained for the required interval.

245 The SPARK POINTS should consist of new sewing needles, supported axially at the ends of linear conductors which are each at least twice the length of the gap. There should be no extraneous body near the gap within a radius of twice its length. A table of approximate striking distances is given in Appendix D. This table should be used in connection with tests made by the spark-gap methods.

246 A NON-INDUCTIVE RESISTANCE of about one-half ohm per volt should be inserted in series with each terminal of the gap so as to keep the discharge current between the limits of one-quarter ampere and 2 amperes. The purpose of the resistance is to limit the current in order to prevent the surges which might otherwise occur at the time of break-down.

247 2. The VOLTMETER gives a direct reading, and the different values of the voltage can be read during the application and duration of the test. It is suitable for all voltages, and does not introduce disturbances into the test circuit.

248 In VOLTMETER MEASUREMENTS, the voltmeter should, in general, derive its voltage from the high-tension testing circuit either directly or through

an auxiliary ratio transformer. It is permissible, however, to measure the voltage at other places,—for example, on the primary of the transformer, provided the ratio of transformation does not materially vary during the test; or that proper account is taken thereof.

249 Spark Gap and Voltmeter. The spark gap may be employed as a check upon the voltmeter used in high-tension tests in order to determine the transformation ratio of the transformer, the variation from the sine wave form and the like. It is also useful in conjunction with voltmeter measurements to limit the stress applied to the insulating material.

(*D*) Apparatus for Supplying Test Voltage.

250 The Generator or Circuit supplying voltage for the test should have ample current carrying capacity, so that the current which may be taken for charging the apparatus to be tested will not materially alter the wave form nor otherwise materially change the voltage.

The Testing Transformer should be such that its ratio of transformation does not vary more than 10 per cent when delivering the charging current required by the apparatus under test. (This may be determined by short-circuiting the secondary or high voltage winding of the testing transformer and supplying 1/10 of the primary voltage to the primary under this condition. The primary current that flows under this condition is the maximum which should be permitted in regular dielectric test.)

251 The Voltage Control may be secured in either of several ways, which in order of preference, are as follows:

252 1. By generator field circuit.

253 2. By magnetic commutation.

254 3. By change in transformer ratio.

255 4. By resistance or choke coils.

256 In Generator Voltage Control, the voltage of the generator should preferably be about its approximate normal rated load value when the full testing voltage is attained, which requires that the ratio of the raising transformer be such that the full testing voltage is reached when the generator voltage is normal. This avoids the instability in the generator which may occur if a considerable leading current is taken from it when it has low voltage and low field current.

257 In Magnetic Commutation, the control is effected by shunting the magnetic flux through a secondary coil so as to vary the induction through the coil and the voltage induced in it. The shunting should be effected smoothly, thus avoiding sudden changes in the induced voltage.

258 In Transformer Voltage Control, by change of ratio, it is necessary that the transition from one step to another be made without interruption of the test voltage, and by steps sufficiently small to prevent surges in the testing circuit. The necessity of this precaution is greater as the inductance or the static capacity of the apparatus in the testing circuit under test is greater.

259 When Resistance Coils or Reactors are used for voltage control, it is desirable that the testing voltage should be secured when the controlling resistance or reactance is very nearly or entirely out of circuit in order that the disturbing effect upon the wave form which results may be negligible at the highest voltage.

F. CONDUCTIVITY.

260 Copper. The conductivity of copper in annealed wires and in electric cables should not be less than 98 per cent of the Annealed Copper Standard, and the conductivity of hard-drawn copper wires should not be less than 95 per cent of the Annealed Copper Standard. The Annealed Copper Standard represents a mass-resistivity of 0.153022 ohm per meter-gram at 20 deg. cent. or 873.75 ohms per mile-pound at 20 deg. cent.; or using a density of 8.89, a volume-resistivity of 1.72128 microhm-cm., or microhms in a cm. cube, at 20 deg. cent. or 0.67767microhm-inch at 20 deg. cent.

G. RISE OF TEMPERATURE.

(I) *MEASUREMENT OF TEMPERATURE.*

(*A*) Methods.

261 There are two methods in common use for determining the rise in temperature, *viz.*: (1) by thermometer, and (2) by increase in resistance of an electric circuit.

262 1. By Thermometer. The following precautions should be observed in the use of thermometers:

263 *a.* Protection. The thermometers indicating the room temperature should be protected from thermal radiation emitted by heated bodies, or from draughts of air or from temporary fluctuations of temperature. Several room thermometers should be used. In using the thermometer by applying it to a heated part, care should be taken so to protect its bulb as to prevent radiation from it, and, at the same time, not to interfere seriously with the normal radiation from the part to which it is applied.

264 *b.* Bulb. When a thermometer is applied to the free surface of a machine, it is desirable that the bulb of the thermometer should be covered by a pad of definite area. A convenient pad may be formed of cotton waste in a shallow circular box about one and a half inches in diameter, through a slot in the side in which the thermometer bulb is inserted. An unduly large pad over the thermometer tends to interfere with the natural liberation of heat from the surface to which the thermometer is applied.

265 2. By Increase in Resistance. The resistance may be measured either by the Wheatstone bridge, the Thomson or Kelvin double bridge, the potentiometer method, or the ammeter and voltmeter method. If a temperature coefficient must be assumed, its value for copper may be taken to be 0.00394 per deg. cent. from and at 20 deg. cent., or 0.00428 per deg. cent. from and at 0 deg. cent. This value holds for average commercial *annealed* copper. If the copper wire is hard-drawn, or if the conductivity is known, a different value of temperature coefficient should be taken, according to the explanation and discussion of the temperature coefficient in Appendix E.

The temperature rise may be determined either (1) by dividing the per cent increase of initial resistance by the temperature coefficient for the initial temperature expressed in per cent; or (2) by multiplying the increase in per cent of the initial resistance by T plus the initial temperature in degrees cent., and then dividing the product by 100. ($-T$ is the "inferred absolute zero temperature of resistance" and is given in the last column of the table in Appendix E. For average commercial *annealed* copper it is 233.8).

266 3. Comparison of Methods. In electrical conductors, the rise of temperature should be determined by their increase of resistance where practicable. Temperature elevations measured in this way are usually in excess of temperature elevations measured by thermometers. In very low resistance circuits, thermometer measurements are frequently more reliable than measurements by the resistance method. Where a thermometer applied to a coil or winding, indicates a higher temperature elevation than that shown by resistance measurement, the thermometer indication should be accepted.

(*B*) Normal Conditions for Tests.

267 1. Duration of Tests. The temperature should be measured after a run of sufficient duration for the apparatus to reach a practically constant temperature. This is usually from 6 to 18 hours, according to the size and construction of the apparatus. It is permissible, however, to shorten the time of the test by running a lesser time on an overload in current and voltage, then reducing the load to normal, and maintaining it thus until the temperature has become constant.

268 2. Room Temperature. The rise of temperature should be referred to the standard condition of a room temperature of 25 deg. cent.

269 Temperature Correction. If the room temperature during the test

differs from 25 deg. cent., correction on account of difference in resistance should be made by changing the observed rise of temperature by one-half per cent for each degree centigrade. Thus with a room temperature of 35 deg. cent., the observed rise of temperature has to be decreased by 5 per cent, and with a room temperature of 15 deg. cent., the observed rise of temperature has to be increased by 5 per cent. In certain cases, such as shunt-field circuits without rheostat, the current strength will be changed by a change of room temperature. The heat-production and dissipation may be thereby affected. Correction for this should be made by changing the observed rise in temperature in proportion as the $I^2 R$ loss in the resistance of the apparatus is altered owing to the difference in room temperature.

270 3. Barometric Pressure. Ventilation. A barometric pressure of 760 mm. and normal conditions of ventilation should be considered as standard, and the apparatus under test should neither be exposed to draught nor enclosed, except where expressly specified. The barometric pressure needs to be considered only when differing greatly from 760 mm.

271 Barometric Pressure Correction. When the barometric pressure differs greatly from the standard pressure of 760 mm. of mercury, as at high altitudes, a correction should be applied. In the absence of more nearly accurate data, a correction of one per cent of the observed rise in temperature for each 10 mm. deviation from the 760-mm. standard is recommended. For example at a barometric pressure of 680 mm. the observed rise of temperature is to be reduced by $\frac{760-680}{10} = 8$per cent.

(II) *LIMITING TEMPERATURE RISE.*

272 General. The temperature of electrical machinery under regular service conditions, should never be allowed to remain at a point at which permanent deterioration of its insulating material takes place.

273 Limits Recommended. It is recommended that the following maximum values of temperature elevation, referred to a standard room temperature of 25 degrees centigrade, at rated load under normal conditions of ventilation or cooling, should not be exceeded.

(*A*) Machines in General.

274 In commutating machines, rectifying machines, pulsating-current generators, synchronous machines, synchronous commutating machines and unipolar machines, the temperature rise in the parts specified should not exceed the following:

275 Field and armature, 50 deg. cent.

276 Commutator and brushes, by thermometer, 55 deg. cent.

277 Collector rings, 65 deg. cent.

278 Bearings and other parts of machine, by thermometer, 40 deg. cent.

279 (*B*) Rotary Induction Apparatus. The temperature rise should not exceed the following:

280 Electric circuits, 50 deg. cent., by resistance.

281 Bearings and other parts of the machine 40 deg. cent., by thermometer.

282 In squirrel-cage or short-circuited armatures, 55 deg. cent., by thermometer, may be allowed.

(*C*) Stationary Induction Apparatus.

283 *a*. Transformers for Continuous Service. The temperature rise should not exceed 50 deg. cent. in electric circuits, by resistance; and in other parts, by thermometer.

284 *b*. Transformers for Intermittent Service. In the case of transformers intended for intermittent service, or not operating continuously at rated load, but continuously in circuit, as in the ordinary case of lighting transformers, the temperature elevation above the surrounding air-temperature should not exceed 50 deg. cent., by resistance in electric circuits and by thermometer in other parts, after the period corresponding to the term of rated load. In this instance, the test load should not be applied

until the transformer has been in circuit for a sufficient time to attain the temperature elevation due to core loss. With transformers for commercial lighting, the duration of the rated-load test may be taken as three hours, unless otherwise specified.

285 *c.* REACTORS, INDUCTION- AND MAGNETO-REGULATORS. Electric circuits by resistance and other parts by thermometer, 50 deg. cent.

286 *d.* LARGE APPARATUS. Large generators, motors, transformers, or other apparatus in which reliability and reserve overload capacity are important, are frequently specified not to rise in temperature more than 40 deg. cent. under rated load and 55 deg. cent. at rated overload. It is, however, ordinarily undesirable to specify lower temperature elevations than 40 deg. cent. at rated load, measured as above.

(*D*) RHEOSTATS.

287 In RHEOSTATS, HEATERS and other electrothermal apparatus, no combustible or inflammable part or material, or portion liable to come in contact with such material, should rise more than 50 deg. cent. above the surrounding air under the service conditions for which it is designed.

288 *a.* PARTS OF RHEOSTATS. Parts of rheostats and similar apparatus rising in temperature, under the specified service conditions, more than 50 deg. cent., should not contain any combustible material, and should be arranged or installed in such a manner that neither they, nor the hot air issuing from them, can come in contact with combustible material.

(*E*) LIMITS RECOMMENDED IN SPECIAL CASES.

289 *a.* HEAT RESISTING INSULATION. With apparatus in which the insulating materials have special heat-resisting qualities, a higher temperature elevation is permissible.

290 *b.* HIGH AIR TEMPERATURE. In apparatus intended for service in places of abnormally high temperature, a lower temperature elevation should be specified.

291 *c.* APPARATUS SUBJECT TO OVERLOAD. In apparatus which by the nature of its service may be exposed to overload, or is to be used in very high voltage circuits, a smaller rise of temperature is desirable than in apparatus not liable to overloads or in low-voltage apparatus. In apparatus built for conditions of limited space, as railway motors, a higher rise of temperature must be allowed.

292 *d.* APPARATUS FOR INTERMITTENT SERVICE. In the case of apparatus intended for intermittent service, except railway motors, the temperature elevation which is attained at the end of the period corresponding to the term of rated load, should not exceed the values specified for machines in general. In such apparatus, including railway motors, the temperature elevation should be measured after operation, under as nearly as possible the conditions of service for which the apparatus is intended, and the conditions of the test should be specified.

II. OVERLOAD CAPACITIES.

293 PERFORMANCE WITH OVERLOAD. All apparatus should be able to carry the overload hereinafter specified without serious injury by heating, sparking, mechanical weakness, etc., and with an additional temperature rise not exceeding 15 deg. cent., above those specified for rated loads, the overload being applied after the apparatus has acquired the temperature corresponding to rated load continuous operation. Rheostats to which no temperature rise limits are attached are naturally exempt from this additional temperature rise of 15 deg. cent. under overload specified in these rules.

294 NORMAL CONDITIONS. Overload guarantees should refer to normal conditions of operation regarding speed, frequency, voltage, etc., and to non-inductive conditions in alternating apparatus, except where a phase displacement is inherent in the apparatus.

295 OVERLOAD CAPACITIES RECOMMENDED. The following overload capacities are recommended:

296 *a*. GENERATORS. Direct-current generators and alternating-current generators, 25 per cent for two hours.

297 *b*. MOTORS. Direct-current motors, induction motors and synchronous motors, not including railway and other motors intended for intermittent service, 25 per cent for two hours, and 50 per cent for one minute.

298 *c*. CONVERTERS. Synchronous converters, 25 per cent for two hours, 50 per cent for one-half hour.

299 *d*. TRANSFORMERS AND RECTIFIERS. Constant-potential transformers and rectifiers, 25 per cent for two hours; except in transformers connected to apparatus for which a different overload is guaranteed in which case the same guarantees shall apply for the transformers as for the apparatus connected thereto.

300 *e*. EXCITERS. Exciters of alternators and other synchronous machines, 10 per cent more overload than is required for the excitation of the synchronous machine at its guaranteed overload, and for the same period of time. All exciters of alternating-current, single-phase or polyphase generators, should be able to give at their rated speed, sufficient voltage and current to excite their alternators, at the rated speed, to the full-load terminal voltage, at the rated output in kilovolt-amperes and with 50 per cent power factor.

301 *f*. A CONTINUOUS-SERVICE RHEOSTAT, such as an armature- or field-regulating rheostat, should be capable of carrying without injury for two hours, a current 25 per cent greater than that at which it is rated. It should also be capable of carrying for one minute a current 50 per cent greater than its rated load current, without injury. This excess of capacity is intended for testing purposes only, and this margin of capacity should not be relied upon in the selection of the rheostat.

302 *g*. An INTERMITTENT SERVICE OR MOTOR-STARTING RHEOSTAT is used for starting a motor from rest and accelerating it to rated speed. Under ordinary conditions of service, and unless expressly stated otherwise, a motor is assumed to start in fifteen seconds and with 150 per cent of rated current strength. A motor-starter should be capable of starting the motor under these conditions once every four minutes for one hour.

303 (*a*) This TEST may be carried out either by starting the motor at four-minute intervals, or by placing the starter at normal temperature across the maximum voltage for which it is marked, and moving the lever uniformly and gradually from the first to the last position during a period of fifteen seconds, the current being maintained substantially constant at said 50 per cent excess, by introducing resistance in series or by other suitable means.

304 (*b*) OTHER RHEOSTATS FOR INTERMITTENT-SERVICE are employed under such special and varied conditions, that no general rules are applicable to them.

III. VOLTAGES AND FREQUENCIES.

A. VOLTAGES.

305 DIRECT-CURRENT GENERATORS. In direct-current, low-voltage generators, the following average terminal voltages are in general use and are recommended:

125 volts. 250 volts. 600 volts.

306 LOW-VOLTAGE CIRCUITS. In direct-current low-voltage circuits, the following terminal voltages are in general use and are recommended:

115 volts. 230 volts. 550 volts.

In alternating-current low-voltage circuits, the following terminal voltages are in general use and are recommended.

110 volts. 220 volts. 440 volts. 550 volts.

307 PRIMARY DISTRIBUTION CIRCUITS. In alternating-current, constant-potential, primary-distribution circuits, an average voltage of 2,200 volts, with step-down transformer ratios 1/10 and 1/20, is in general use, and is recommended.

308 TRANSMISSION CIRCUITS. In alternating-current constant-potential transmission circuits, the following impressed voltages are recommended.
6,600 11,000 22,000 33,000 44,000 66,000 88,000 110,000

309 TRANSFORMER RATIO. It is recommended that the standard transformer ratios should be such as to transform between the standard voltages above named. The ratio will, therefore, usually be an exact multiple of 5 or 10, *e.g.*, 2,200 to 11,000; 2,200 to 44,000.

310 RANGE IN VOLTAGE. In alternating-current generators, or generating systems, a range of terminal voltage should be provided from rated voltage at no load to 10 per cent in excess thereof, to cover drop in transmission. If a greater range than ten per cent is specified, the generator should be considered as special.

B. FREQUENCIES.

311 IN ALTERNATING-CURRENT CIRCUITS, the following frequencies are standard:

25 cycles 60 cycles

312 These frequencies are already in extensive use and it is deemed advisable to adhere to them as closely as possible.

IV. GENERAL RECOMMENDATIONS.

313 NAME PLATES. All electrical apparatus should be provided with a name plate giving the manufacturers' name, the voltage and the current in amperes for which it is designed. Where practicable, the kilowatt capacity, character of current, speed, frequency, type, designation and serial number should be added.

314 DIAGRAMS OF CONNECTIONS. All electrical apparatus when leaving the factory should be accompanied by a diagram showing the electrical connections and the relation of the different parts in sufficient detail to give the necessary information for proper installation.

315 RHEOSTAT DATA. Every rheostat should be clearly and permanently marked with the voltage and amperes, or range of amperes, for which it is designed.

316 COLORED INDICATING LIGHTS. When using colored indicating lights on switch-boards, red should denote danger such as "switch closed," or "circuit alive"; green should denote safety, such as "switch open," or "circuit dead."

317 When white lights are used a light turned on should denote danger, such as "switch closed" or "circuit alive"; while the light out should denote safety, such as "switch open," or "circuit dead." Low-efficiency lamps should be used on account of their lesser liability to accidental burn-out.

318 The use of colored lights is recommended, as safer than white lights.

319 GROUNDING METAL WORK. It is desirable that all metal work near high potential circuits be grounded.

320 CIRCUIT OPENING DEVICES. The following definitions are recommended.

321 *a*. A CIRCUIT-BREAKER is an apparatus for breaking a circuit at the highest current which it may be called upon to carry.

322 *b*. A DISCONNECTING SWITCH is an apparatus designed to open a circuit only when carrying little or no current.

323 *c*. An AUTOMATIC CIRCUIT-BREAKER is an apparatus for breaking a circuit automatically under an excessive strength of current. It should be capable of breaking the circuit repeatedly at rated voltage and at the maximum current which it may be called upon to carry.

V. APPENDICES AND TABULAR DATA.

APPENDIX A. NOTATION.

The following notation is recommended:

	Name of Quantity	Symbol	Unit
324	Voltage, e.m.f., potential difference	E, e,	volt
	Current	I, i,	ampere
	Resistance	R, r,	ohm
	Reactance	X, x,	"
	Impedance	Z, z,	"
	Admittance	Y, y,	mho
	Conductance	G, g,	"
	Susceptance	B, b,	"
	Power	P, p,	watt
	Capacity	C, c,	farad
	Inductance	$\mathfrak{L}$, L,	henry
	Magnetic flux	Φ	maxwell
	Magnetic density	$\mathfrak{B}$,	gauss
	Magnetic force	H,	gilbert per cm.
	Length	L, l,	cm. or inch
	Mass	M, m,	gm. or lb.
	Time	T, t,	second or hour

E_m, I_m and B_m should preferably be used for maximum cyclic values, e, i and p for instantaneous values, E and I for r.m.s. values (see Sec. 5g.) and P for the average value or effective power. These distinctions are not necessary in dealing with continuous-current circuits. Vector quantities are preferably represented by bold face capitals.

APPENDIX B.—RAILWAY MOTORS.

(I) *RATING.*

325 Introductory Note on Rating. Railway motors usually operate in a service in which both the speed and the torque developed by the motor are varying almost continually. The average requirements, however, during successive hours in a given class of service are fairly uniform. On account of the wide variation of the instantaneous loads, it is impracticable to assign any simple and definite rating to a motor which will indicate accurately the absolute capacity of a given motor or the relative capacity of different motors under service conditions. It is also impracticable to select a motor for a particular service without much fuller data with regard both to the motor and to the service than is required, for example, in the case of stationary motors which run at constant speeds.

326 Scope of Nominal Rating. It is common usage to give railway motors a nominal rating in horse power on the basis of a one-hour test. As above explained, a simple rating of this kind is not a proper measure of service capacity. This nominal rating, however, indicates approximately the maximum output which the motor should ordinarily be called upon to develop during acceleration. Methods of determining the continuous capacity of a railway motor for service requirements are given under a subsequent heading.

327 The Nominal Rating of a railway motor is the horse-power output at the car-axle, that is, including gear and other transmission losses, which gives a rise of temperature above the surrounding air (referred to a room temperature of 25 deg. cent.) not exceeding 90 deg. cent. at the commutator and 75 deg. cent. at any other part after one hour's continuous run at its rated voltage (and frequency, in the case of an alternating-current motor) on a stand, with the motor-covers removed, and with natural ventilation. The rise in temperature is to be determined by thermometer, but the resistance of no electrical circuit in the motor shall increase more than 40 per cent during the test.

(II) *SELECTION OF MOTOR FOR SPECIFIED SERVICE.*

328 General Requirements. The suitability of a railway motor for a specified service depends upon the following considerations:

329 *a.* Mechanical ability to develop the requisite torque and speeds as given by its speed-torque curve.

330 *b.* Ability to commutate successfully the current demanded.

331 *c.* Ability to operate in service without occasioning a temperature rise in any part which will endanger the life of the insulation.

332 Operating Conditions, Typical Run. The operating conditions which are important in the selection of a motor include the weight of load, the schedule speed, the distance between stops, the duration of stops, the rate of acceleration and of braking retardation, the grades and the curves, with these data at hand, the outputs which are required of the motor may be determined, provided the service requirements are within the limits of the speed-torque curve of the motor. These outputs may be expressed in the form of curves giving the instantaneous values of current and of voltage which must be applied to the motor. Such curves may be laid out for the entire line, but they are usually constructed only for a certain average or typical run, which is fairly representative of the conditions of service. To determine whether the motor has sufficient capacity to perform the service safely, further tests or investigations must be made.

333 Capacity Test of Railway Motor in Service. The capacity of a railway motor to deliver the necessary output may be determined by measurement of its temperature after it has reached a maximum in service. If a running test cannot be made under the actual conditions of service, an equivalent test may be made in a typical run back and forth, under such conditions of schedule speed, length of run, rate of acceleration, etc., that the test cycle of motor losses and conditions of ventilation are essentially the same as would be obtained in the specified service.

334 Methods of Comparing Motor Capacity with Service Requirements. Where it is not convenient to test motors under actual service conditions or in an equivalent typical run, recourse may be had to one of the two following methods of determining temperature rise now in general use:

335 1. Method by Losses and Thermal Capacity Curves. The heat developed in a railway motor is carried partly by conduction through the several parts and partly by convection through the air to the motor frame whence it is distributed to the outside air. As the temperature of the several parts is thus dependent not only upon their own internal losses but also upon the temperature of neighboring parts, it becomes necessary to determine accurately the actual value and distribution of losses in a railway motor for a given service and reproduce them in an equivalent test-run. The results of a series of typical runs expressed in the form of thermal capacity curves will give the relation between degrees rise per watt loss in the armature and in the field for all ratios of losses between them met with in the commercial application of a given motor.

336 This method consists, therefore, in calculating the several internal motor losses in a specified service and determining the temperature rise with these losses from thermal capacity curves giving the degrees rise per watt loss as obtained in experimental track tests made under the same conditions of ventilation.

337 The following motor losses cause its heating and should be carefully determined for a given service: $I^2 R$ in the field; $I^2 R$ in the armature; $I^2 R$ in the brush contacts, core loss and brush friction.

338 The loss in the bearings (in the case of geared motors) also adds somewhat to the motor-heating, but owing to the variable nature of such losses they are generally neglected in making calculations.

339 2. Method by Continuous Capacity of Motor. The essential losses in the motor, as found in the typical run, are in most cases those in the

motor windings and in the core. The mean service conditions may be expressed in terms of the current which would produce the same losses in the motor windings and the voltage which, with that current, would produce the same core losses as the average in service. The continuous capacity of the motor is given in terms of the amperes which it will carry when run on a testing stand—with covers on or off, as specified—at different voltages, say, 40, 60, 80 and 100 per cent of the rated voltage—with a temperature rise not exceeding 90 deg. cent at the commutator and 75 deg. cent at any other part, provided the resistance of no electric circuit in the motor increases more than 40 per cent. A comparison of the equivalent service conditions with the continuous capacity of the motor will determine whether the service requirements are within the safe capacity of the motor.

340 This method affords a ready means of determining whether a specified service is within the capacity of a given motor and it is also a convenient approximate method for comparing the service capacities of different motors.

APPENDIX C. PHOTOMETRY AND LAMPS.

341 CANDLE-POWER. The luminous intensity of sources of light is expressed in candle-power. The unit of candle-power is the international candle maintained by the Bureau of Standards at Washington, D. C. The Hefner unit is 0.90 of the international candle.

342 LUMEN. The total flux of light from a source is equal to its mean spherical intensity multiplied by 4π. The unit of flux is called the lumen. A lumen is the $\frac{1}{4\pi}$th part of the total flux of light emitted by a source having a mean spherical intensity of one candle-power.

344 ILLUMINATION. The fundamental physical unit of illumination is the centimeter-candle, or lumen per square centimeter of incident surface. This is a very intense illumination. It is, therefore, convenient to express illumination practically in thousandths of the fundamental unit; *i.e.*, in millilumens per sq. cm. In English-speaking countries, the unit of illumination commonly employed is the foot-candle or lumen per square foot. A foot-candle is nearly the same illumination as a millilumen per sq. cm. and is actually the more intense in the ratio 1.0764; so that n foot-candles $= 1.0764 \times n$ millilumens per sq. cm. A meter candle or lumen per square meter, is called a "lux". A foot-candle is 10.764 lux, and a millilumen per sq. cm. is exactly 10 lux.

346 The EFFICIENCY OF ELECTRIC LAMPS is properly stated in terms of lumens per watt at lamp terminals. This use of the term efficiency is to be considered as special, and not to be confused with the generally accepted definition of efficiency in Sec. 84.

347 *a*. EFFICIENCY, AUXILIARY DEVICES. In illuminants requiring auxiliary power-consuming devices outside of the luminous body, such as steadying resistances in constant potential arc lamps, a distinction should be made between the net efficiency and the gross efficiency of the lamp. This distinction should always be stated. The gross efficiency should include the power consumed in the auxiliary resistance, etc. The net efficiency should, however, include the power consumed in the controlling mechanism of the lamp itself. Comparison between such sources of light should be made on the basis of gross efficiency, since the power consumed in the auxiliary device is essential to the operation.

348 A STANDARD CIRCUIT VOLTAGE of 110 volts, or a multiple thereof may be assumed, except where expressly stated otherwise.

349 WATTS PER CANDLE. The specific consumption of an electric lamp is its watt consumption per mean spherical candle-power. "Watts per candle" is the term used commercially in connection with incandescent lamps, and denotes, watts per mean horizontal candle-power.

350 PHOTOMETRIC TESTS in which the results are stated in candle-power should be made at such a distance from the source of light that the latter may be regarded as practically a point. Where tests are made at shorter distances, as for example in the measurement of lamps with reflectors, the results should always be given as "apparent candle-power" at the distance employed, which distance should always be specifically stated.

351 BASIS FOR COMPARISON. Either the total flux of light in lumens, or the mean spherical candle-power, should always be used as the basis for comparing various luminous sources with each other, unless there is a clear understanding or statement to the contrary.

352 INCANDESCENT LAMPS, RATING. It is customary to rate incandescent lamps on the basis of their mean horizontal candle-power; but in comparing incandescent lamps in which the relative distribution of luminous intensity differs, the comparison should be based on their total flux of light measured in lumens, or on their mean spherical candle-power.

352a LIFE TESTS. Similar filaments may be assumed to operate at the same temperature only when their lumens per watt consumed are the same. Life tests are comparable only when conducted under similar conditions as to filament temperatures.

353 The SPHERICAL REDUCTION-FACTOR of a lamp

$$= \frac{\text{mean spherical candle-power}}{\text{mean horizontal candle-power}}$$

354 The TOTAL FLUX of light in lumens emitted by a lamp $= 4\pi \times$ mean horizontal candle-power $\times$ spherical reduction-factor.

355 The SPHERICAL REDUCTION-FACTOR should only be used when properly determined for the particular type and characteristics of each lamp. The spherical reduction-factor permits of substantially accurate comparisons being made between the total lumens, or mean spherical candle-powers of different types of incandescent lamps, and may be used in the absence of proper facilities for direct measurement of the total lumens, or mean spherical candle-power.

356 "READING DISTANCE." Where standard photometric measurements are impracticable, approximate measurements of illuminants such as street lamps may be made by comparing their "reading distances;" *i.e.*, by determining alternately the distances at which an ordinary size of reading print can just be read, by the same person or persons, when all other light is screened. The angle below the horizontal at which the measurement is made should be specified when it exceeds 15 degrees. Reading-distance methods usually involve the comparison of very faint illuminations and hence the results may be seriously affected by the Purkinje effect.

357 In COMPARING DIFFERENT LUMINOUS SOURCES not only should their candle-power be compared, but also their relative form, brightness, distribution of illumination and character of light.

357a The following symbols are recommended in connection with photometry:

Photometric magnitude	Symbol	Unit
Intensity of light.	I	International candle.
Luminous flux.	F	Lumen.
Illumination.	E	Lumen/cm.², foot-candle.
Specific radiation.	R	Foot-candle.
Brightness.	b	Candle/cm.²
Quantity.	Q	Candle.
Lighting.	L	Lumen-second, lumen-hour.

APPENDIX D. SPARKING DISTANCES.

358 Table of Sparking Distances in Air between Opposed Sharp Needle-Points, for Various Root-Mean-Square Sinusoidal Voltages, in inches and in centimeters. The table applies to the conditions specified in Secs. 240–246.

359

Kilovolts R.M.S.	Distance. Inches	Distance. Cm.
5	0.225	0.57
10	0.47	1.19
15	0.725	1.84
20	1.0	2.54
25	1.3	3.3
30	1.625	4.1
35	2.0	5.1
40	2.45	6.2
45	2.95	7.5
50	3.55	9.0
60	4.65	11.8
70	5.85	14.9
80	7.1	18.0
90	8.35	21.2
100	9.6	24.4
110	10.75	27.3
120	11.85	30.1
130	12.90	32.8
140	13.95	35.4
150	15.0	38.1
160	16.05	40.7
170	17.10	43.4
180	18.15	46.1
190	19.20	48.8
200	20.25	51.4
210	21.30	54.1
220	22.35	56.8
230	23.40	59.4
240	24.45	62.1
250	25.50	64.7
260	26.50	67.3
270	27.50	69.8
280	28.50	72.4
290	29.50	74.9
300	30.50	77.4

APPENDIX E. TEMPERATURE COEFFICIENT OF COPPER.

360 The fundamental relation between the rise of temperature and the increase of resistance of copper may be expressed thus:

$$R_t = R_{t_1} \ (1 + \alpha_{t_1} \ [t - t_1])$$

where R_t is the resistance at any temperature t deg. cent.; R_{t_1} is the resistance at any "initial temperature" (or "temperature of reference") t_1 deg. cent.; and α_{t_1} is the temperature coefficient from and at the initial temperature t_1 deg. cent. Obviously the temperature coefficient is different for different initial temperatures, and this variation is shown in the horizontal rows of the table below. Furthermore, it has been shown that the temperature coefficient is different for different conductivities, and that the temperature coefficient is substantially proportional to the conductivity. The results of this simple law are shown by the vertical columns of the table below.

TEMPERATURE COEFFICIENTS OF COPPER FOR DIFFERENT INITIAL TEMPERATURES AND DIFFERENT CONDUCTIVITIES

Ohms per meter-gram at 20 deg. cent	Per cent conductivity	α_0	α_{15}	α_{20}	α_{25}	α_{30}	α_{50}	$-T$ "Inferred absolute zero"
0.16108	95	0.00405	0.00381	0.00374	0.00367	0.00361	0.00336	−247.2
0.15940	96	0.00409	0.00386	0.00378	0.00371	0.00364	0.00340	−244.4
0.15776	97	0.00414	0.00390	0.00382	0.00375	0.00368	0.00343	−241.7
0.15727	97.3	0.00415	0.00391	0.00383	0.00376	0.00369	0.00344	−240.9
0.15614	98	0.00418	0.00394	0.00386	0.00379	0.00372	0.00346	−239.0
0.15457	99	0.00423	0.00398	0.00390	0.00383	0.00375	0.00349	−236.4
0.153022	100	0.00428	0.00402	0.00394	0.00386	0.00379	0.00352	−234.8
0.15151	101	0.00432	0.00406	0.00398	0.00390	0.00383	0.00355	−231.3

The quantity $(-T)$ given in the last column of the above table is the calculated temperature on the centigrade scale at which copper of the particular conductivity concerned would have zero electrical resistance *provided* the temperature coefficient between 0 deg. cent and 100 deg. cent. applied continuously down to the absolute zero. The usefulness of this "inferred absolute zero temperature of resistance" in calculating temperature rise is evident from the following formula:

$$t - t_1 = \frac{R_t - R_{t_1}}{R_{t_1}} (T + t_1)$$

The presentation of the above table is intended to emphasize the desirability of determining the temperature coefficient rather than assuming it. Actual experimental determination is facilitated by the proportional relation between the temperature coefficient and the conductivity; a measurement of either quantity gives both. However, if a temperature coefficient *must* be assumed, the best value to take for average commercial *annealed* copper wire is that given in the table for 100 per cent conductivity, *viz.*,

$$\alpha_0 = 0.00428, \ \alpha_{20} = 0.00394, \ \alpha_{25} = 0.00386$$

This is the value recommended for wire wound on instruments and machines, since they are generally wound with annealed wire and experiments have shown that the distortions due to the winding of the wire do not appreciably affect the temperature coefficient.

If a value must be assumed for *hard-drawn* copper wire, the value recommended is that given in the table for 97.3 per cent conductivity, *viz.*,

$$\alpha_0 = 0.00415, \ \alpha_{20} = 0.00383, \ \alpha_{25} = 0.00376$$

The temperature coefficients in fahrenheit degrees are given by dividing any α above by 1.8. Thus, the 20 deg. cent. or 68 deg. fahr. temperature coefficient for copper of 100 per cent conductivity is 0.00394 per deg. cent., or 0.00219 per deg. fahr.

APPENDIX F. HORSEPOWER.

361 In view of the fact that a horsepower defined as 550 foot-pounds per second represents a power which varies slightly with the latitude and altitude (from 743.3 to 747.6 watts) and also in view of the fact that different authorities differ as to the precise value of the horsepower in watts, *the Standards Committee has adopted* 746 *watts as the value of the horsepower.* The number of foot-pounds per second to be taken as one horsepower is therefore such a value at any given place as is equivalent to 746 watts; the number varies from 552 to 549 foot-pounds per second, being 550 at 50 deg. latitude (London), and 550.5 at Washington. The Standards Committee, however, recommends that the kilowatt instead of the horsepower be used generally as the unit of power.

ADDENDA

TO THE

A. I. E. E. STANDARDIZATION RULES

G. Official Actions of the Turin Congress

AND

H. Rating of Electrical Machinery in Different Countries

Printed by order of the Board of Directors in Accordance with the Following Resolution Adopted October 13, 1911:

Resolved, that the Secretary be authorized to publish with the Standardization Rules of the Institute the decisions of the International Electrotechnical Commission at Turin in regard to standard symbology and the direction for indicating advancement of phase in graphic diagrams of alternating current quantities, and a resume of the principal features of the rating of electrical machinery of the leading foreign countries.

The following appendix, G, covers the principal official actions of the Turin Congress in 1911.

APPENDIX G.—INTERNATIONAL AGREEMENTS OF THE I. E. C.

The following is a brief résumé of the official actions of the International Electrotechnical Commission at Turin in 1911.

(a) *INTERNATIONAL SYMBOLS*

1. Instantaneous values of electrical quantities which vary with the time are to be represented by small letters.

2. Virtual or constant values of electrical quantities to be represented by capital letters.

3. Maximum values of periodic electrical quantities to be represented by capital letters followed by the subscript "*m*".

4. Magnetic quantities, whether constant or variable, to be represented by capital letters of either script, gothic, heavy-faced, or of any special type.

5. Maximum values of magnetic quantities to be represented by capital letters of either script, gothic, heavy-faced, or of any special type, followed by the subscript "*m*".

6. The following quantities to be represented by the following letters:

Electromotive force	E, e	
Electric quantity	Q, q	
Self-inductance*	$\mathcal{L}$, **L**	†
Magnetic force	$\mathcal{H}$, **H**	†
Magnetic flux density	$\mathcal{B}$, **B**	†
Length	L, l	
Mass	M, m	
Time	T, t	

7. The letters I, E, and R were definitely adopted to represent, respectively, the current, the electromotive force, and the resistance, in the simple algebraical expression of Ohm's law.

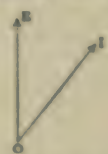
8. In all questions relative to alternating currents, the expression "Reactive Power" is adopted to designate the quantity $UI \sin \phi$.

(b) *DIAGRAMS FOR ALTERNATING CURRENTS*

In the graphical representation of alternating electric and magnetic quantities, advance in phase shall be represented in the counter-clockwise direction.

Note. The impedance of a reactive coil, of resistance R, and inductance L, is $R + \sqrt{-1}\, L\omega$, and that of a condenser of capacity C is

$\dfrac{1}{\sqrt{-1}\, C\omega}$ where ω is equal to $2\pi \times$ frequency.



It follows also that the diagram herewith represents the phase relations in a simple alternating-current circuit containing an impressed electromotive force $O\,E$ and a lagging current $O\,I$.

(c) *RATINGS OF ELECTRICAL MACHINERY AND APPARATUS*

The propositions of the Brussels conference in regard to rating were adopted without modification as follows:

1. The output of electric generators is defined as the electric power available at the terminals.

2. The output of electric motors is defined as the mechanical power available at the shaft.

3. Both the electric and mechanical powers to be expressed in international watts.

*Coefficient of self-induction.

†As examples only.

Appendices H and I give comparisons of methods of rating electrical machinery, and particularly of D-C. machinery, in different countries, as compiled by the Secretary of the International Electrotechnical Commission. See Publication No. 9, "Rating of Electrical Machinery," of the I. E. C. August, 1911.

APPENDIX H.—RATING OF ELECTRICAL MACHINERY

The following are the comparative rules on the rating of direct current generators and motors as compiled by the General Secretary of the International Electrotechnical Commission from the National Rules of six countries as in force in 1911. These comparative rules have been appended to the Standardization Rules by order of the Board of Directors of the American Institute of Electrical Engineers, in order to present the extent of agreement or diversity existing on these rules, in 1911, among the leading electrical engineering societies of the world.

List of documents from which extracts have been made:

BELGIUM. "Prescriptions normales" for the reception of electrical machines and transformers issued by the "Chambre syndicale des Electriciens Belges" in 1908.

FRANCE. General instructions for the delivery and reception of electrical machines and transformers issued by the "Union des Syndicats de l'Electricité" in 1910.

Regulations for tenders, supply and testing of electrical machines and transformers issued by the "Association Alsacienne des Propriétaires d'Appareils à Vapeur," 1906.

GERMANY. Standard rules for the utilization and testing of electrical machines and transformers issued by the "Verband Deutscher Elektrotechniker" in 1910.

GREAT BRITAIN. Report of the British Engineering Standards Committee on "Electrical Machinery" issued in 1907.

SWEDEN. Rules for the testing and reception of electrical machines and transformers issued by the "Association of Swedish Engineers" in 1909.

UNITED STATES. Standardization Rules of the American Institute of Electrical Engineers as contained in its PROCEEDINGS, August, 1911.

ANALYSIS OF THE RULES

POWER

Method of Expressing the Power of Electrical Machines

BELGIUM.
Generators. Kw. at the machine terminals.
Motors. Mechanical horse power at the shaft (75 kg-m. per sec.)

FRANCE.
Generators. Kw. at the machine terminals.
Motors. Kw. or horse power at the shaft (75 kg-m. per sec.).

GERMANY.
Generators. Kw.
Motors. Horse power (75 kg-m. per sec. = 736 W.).

GREAT BRITAIN.
Generators. Kw.
Motors. B.h.p. (1 Brake horse power = 746 W.).

SWEDEN.
Generators. Kw.
Motors. Horse power (75 kg-m. per sec.).

UNITED STATES.
Generators. Kw. at the machine terminals.
Motors. B.h.p. (746 W.) Preferably in kilowatts.

NOTES.—BELGIUM. Motors usually have their power indicated as "H.P.," with consequent confusion as to which is intended; the English b.h.p. being 746 watts, the "cheval-vapeur" being equivalent to 736 watts.

FRANCE. The Association Alsacienne still allows the Poncelet of 100 kg-m. per sec.

RATING

Belgium.

(1) *Intermittent service.* In which the periods of work and rest alternate in minutes.

(2) *Momentary service.* In which periods of work of sufficiently short duration for a stationary temperature not to be reached are followed by periods of rest long enough for the temperature to fall to approximately that of the surrounding air.

(3) *Continuous service.* In which the periods of work are sufficiently prolonged to lead to the establishment of stationary conditions of temperature.

France.

(1) *Continuous service.*

(2) *Variable service.*

(3) *Intermittent service.* (Overhead traveler, crane, lift.)

Germany.

(1) *Intermittent service.* In which the periods of work and rest alternate in minutes. (Motors for cranes, lifts, tramways, and similar apparatus.)

(2) *Short period service.* In which the periods of work are not sufficiently long for the final (rated) temperature to be reached, whilst the periods of rest are long enough for the temperature to fall to approximately that of the surrounding air.

(3) *Continuous service.* In which the periods of work are sufficiently long for the final temperature (rated) to be attained.

Great Britain.

(1) *Continuous working.* The output of generators and motors for continuous working shall be the output at which they can work continuously for six hours and conform to the prescribed tests, and this output shall be defined as the Rated Load.

(2) *Intermittent working.* The output of motors for intermittent working shall be the output at which they can work for one hour and conform to the prescribed tests, and this output shall be defined as the Rated Intermittent Load.

Sweden.

(1) *Continuous service.* In which the temperature reaches stationary conditions.

(2) *Intermittent service.* In which the working periods do not exceed one hour or alternate with intervals of rest of a similar length.

United States.

(1) *Continuous rating.* In which, under load, there is the attainment of approximately stationary temperature.

(2) *Intermittent rating.* In which one minute periods of load and rest alternate until the attainment of approximately stationary conditions of temperature.

(3) *Minute rating.* In which, under load for one minute, no limit of capacity is exceeded, and no permanent change is wrought in the apparatus.

(4) *Variable service rating.* Not yet defined.

Notes.—France. The Association Alsacienne does not recognize "variable service."

Great Britain. The reason for the "six hours" in the explanation of "continuous working" is due to the fact that the Committee considered standardization should not go beyond 1 000 kw., above that capacity being considered as special. One of the aims of standardization being to assist the manufacturer to carry stock, it would scarcely pay to do so above 1 000 kw.

"Continuous working" does not include machines running from week-end to week-end without a stop. The one-hour test under "Intermittent" is likely to be revised.

Sweden. The rated output under continuous service is defined as that output which can be obtained continuously for an unlimited period without the temperature limits specified being exceeded. The rated output under intermittent service is that output which can be obtained continuously for an hour without the temperature limits specified being exceeded.

NAME-PLATES

Information to be Stated on the Name-plates

BELGIUM. Service recognized (intermittent, momentary, for...... hours, or continuous). The rated values of the power, the pressure, the current and the angular speed.

FRANCE. The power for which the machine has been sold.

It is expressed thus: For generators, in kilowatts at the terminals; for motors, in kilowatts, or horse power of 75 kg-m. per second, available at the shaft.

Additional information to be stated: For continuous working, the rated values of the speed in revolutions per minute, the pressure, and the current; for variable working, the limits of pressure and current; for intermittent working (traveller, crane, lift, etc.) the power for a period of one hour, mentioning "intermittent working."

GERMANY. The power for generators to be stated in kilowatts (kw.). Mechanical power to be stated in kilowatts or in horse power (p.s.).

In addition, the name-plate on which the power is stamped, or a special name-plate, must indicate the rated value of the number of revolutions, the pressure and the current.

The name-plate must also indicate the rating: "Intermittent," or "For......hours," or "Continuous."

GREAT BRITAIN. Unless otherwise stated, the output is to be considered to apply to continuous working. In the case of intermittent rating the word "Intermittent" is to be added.

The name-plate shall also indicate: For generators: Kw., volts, amperes, rev. per min. For motors: B.h.p., volts, amperes, rev. per min.; B.h.p (Intermittent), volts, amperes, rev. per min.

SWEDEN. Unless otherwise stated, the output shall be considered as applying to continuous working.

The values stated on the name-plate shall be in conformity with the rules, except it bear the indication "For special purposes."

The following information to be stated: For generators: the kilowatts, volts, amperes, and revs.per minute. For motors: the mechanical power, the volts, amperes, and revs. per minute.

N. B.—The speed shall be the speed with the machine hot, and a tolerance of ± 7% shall be allowed.

The service, adding the words: "For continuous service." "For intermittent service."

For variable service, the respective limits shall be given.

UNITED STATES. Name of the maker, volts, amperes.

When practicable, the kilowatts, the revs. per minute, the type, the character of current, designation and serial number.

COMMUTATION

BELGIUM. Under all conditions not exceeding the rated load, the commutator of a machine shall not require to be cleaned or given other attention more than once a day, with the brushes remaining in the most favorable position.

FRANCE.

Union des Syndicats de L'Electricité. Under all loads included in running free up to the rated load, the brushes being ground and fixed in the most favorable position by means of a previous run, machines with a commutator must be capable of working for the period of the test (specified under *Heating: Duration of Test,*) without it being necessary to glass-paper the commutator or resort to any other method of cleaning.

Association Alsacienne. Unless otherwise specified, when once the brushes have been adjusted in the most favorable position, machines with commutators shall be capable of working, without appreciable sparking or adjustment of brushes, at all loads from no load to rated load, even with sudden changes of current.

Under continuous working, and at any load within the prescribed limits, the working of the commutator shall be such as to require attention (cleaning or lubricating) only at intervals of twelve hours. This condition also applies to collector rings.

GERMANY. Under all conditions of load from one quarter up to the rated load, and without alteration of the position of the brushes, the sparking produced must be so negligible as to permit the machine to work for at least 24 hours without the commutator requiring attention. The brushes to be ground in in the most favorable position.

GREAT BRITAIN. ———

SWEDEN. Unless otherwise specified, the commutation is to be without appreciable sparking from no load to 10 per cent overload and without the position of the brushes being altered.

In the case of machines for variable working, the position of the brushes may be altered. The working position of the brushes is to be indicated.

UNITED STATES. The machine must carry the specified overload without injurious sparking or mechanical weakness.

OVERLOAD

The percentages given below imply an overload in excess of the rated load marked on the name-plate.

BELGIUM. For continuous service. 20 per cent of the rated load for a period equal to one-fifth of the duration of the heating test, with a maximum of one hour.

For intermittent service. 20 per cent of the rated load for one-fifth of an hour.

For momentary service. 20 per cent of the rated load for a period equal to one-fifth of the time marked on the name-plate. 40 per cent of the rated load for 3 minutes.

FRANCE. The test to be applied at the close of the rated load test. All machines must be capable of withstanding, without deterioration or appreciable sparking: 20 per cent of the rated load for one-tenth of the duration of the test for continuous working; 30 per cent of the rated load for 5 minutes.

Motors for intermittent service: 25 per cent of the rated load for 15 minutes; 30 per cent of the rated load for 5 minutes.

GERMANY. For generators and motors: 25 per cent of the rated load for half an hour.

For motors (constant potential): 40 per cent of the rated load for 3 minutes.

GREAT BRITAIN. (see *Heating at Conclusion of Overload Test*)

SWEDEN. 25 per cent in excess of the rated current without injurious sparking. Adjustment of brushes permitted.

UNITED STATES. For generators: 25 per cent of the rated load for 2 hours.

For motors (continuous working): 25 per cent of the rated load for 2 hours; 50 per cent of the rated load for 1 minute.

NOTES.—BELGIUM. The machine must be capable of sustaining the overload during the specified period without adjustment of the brushes. The overload test can be carried out at the close of the rated load test, in which case the rise in temperature must not exceed the limits prescribed for the rated load by more than 10 deg. cent.

FRANCE. The Association Alsacienne also specifies:

For motors intended to work for prolonged periods, an overload test of 40 per cent for three minutes.

All motors must be capable of withstanding an increase of 30 per cent in the rated speed for a period of five minutes.

GERMANY. The overload test is to be applied without reference to the temperature rise, and it must be commenced with the machine at such a temperature as to prevent the prescribed limits being exceeded.

At constant angular speed, generators must be capable of maintaining constant pressure with an overload of 15 per cent.

VARIATION OF PRESSURE AND SPEED

BELGIUM.

Generators. The pressure variation of a generator is measured by the greatest difference observed, at constant speed, between any two values of the pressure corresponding with loads, the current of which does not exceed that defined by the rated load, the pressure being regulated, at this current, to the rated load value. The brushes to remain adjusted in the working position.

NOTE.—The excitation of a generator, intended to work at constant pressure, must be capable of maintaining the rated value of the pressure under normal conditions of angular speed, at all loads from no load up to and including 1.15 times the rated load current

Motors. The speed variation is defined as the difference in angular speed at rated load and at no load at normal working pressure, and without alteration of field rheostats adjusted for the rated load.

FRANCE.

Generators. The pressure variation shall be measured in passing from the rated load to no load, at constant speed, in the case of *self-exciting* machines, whilst maintaining constant the resistance in the field circuit; in the case of *separately excited* machines, whilst maintaining constant the exciting current. During this test, and unless otherwise specified, the brushes shall remain fixed in the rated load sparkless position.

Motors. The speed variation shall be measured in passing from the rated load to no load, with constant pressure at the terminals.

GERMANY. At constant rated load speed and excitation, the pressure to be observed at, at least, four points practically equidistant on the load curve. The greatest difference between the observed pressures is a measure of the variation. In regard to the adjustment of brushes, the conditions are to be governed according to the rating.

GREAT BRITAIN. ———

SWEDEN. At constant rated load speed and excitation, the ratio of the increase in pressure at rated load and the pressure at no load, shall be taken:

(1) By observing the values of the pressure at no load and at rated load.

(2) By observing the values of the pressure with increasing values of the field current, both with no load on the armature and with the rated load current in the ermature. Tolerance allowed ± 2 per cent.

UNITED STATES.

Generators. Ratio of maximum variation of terminal pressure from the normal (occurring between rated load and no load) to the rated load pressure.

Motors. Ratio of maximum variations in speed from the normal (occurring between rated load and no load) to the rated load speed.

HEATING

General Notes

BELGIUM. The test is to be carried out as nearly as possible under ordinary working conditions. An overload may be applied at the commencement of the test in order to attain more rapidly the final conditions of temperature.

The maximum temperature is to be compatible with the insulation employed. Special precautions are to be taken when employing thermometers. Unless otherwise specified, apparatus for variable speed and pressure shall be tested under the most severe conditions.

FRANCE. The maximum temperature is to be compatible with the insulation employed.

GERMANY. The tests are to be carried out under the conditions of service specified. Any ventilation which would naturally be produced under ordinary working conditions and which was provided for in the design may be imitated during the test. If a thermometer is employed,

it is recommended that the bulb be covered with tinfoil and every precaution taken to prevent loss of heat.

GREAT BRITAIN. The temperature allowed depends on the character of the insulation.

The temperature limits specified do not cover cases in which cotton, paper, and its preparations, linen, or similar materials are used solely as vehicles for insulation varnishes, or enamels, capable of continuously resisting temperatures above 125 deg. cent. Machines in which such materials are employed are dealt with separately.

A much higher temperature rise than that specified on page 44, may be permitted in machines in which the insulation is secured by means of special materials designed to resist high temperatures, but the amount of permissible temperature rise must depend on the properties of the insulating materials and the method of construction and must be settled specially for each class of machine.

SWEDEN. The test is to be carried out as nearly as possible under ordinary working conditions.

UNITED STATES. The temperature allowed must not be such as to be detrimental to the insulation under ordinary working conditions.

An overload may be applied to shorten the duration of the test.

Methods

BELGIUM. By increase in resistance, if this method is practicable. Otherwise by means of thermometers.

FRANCE. Temperatures ascertained by means of thermometers, placed in the hottest part accessible; nevertheless, in the case of exciting circuits and all stationary windings, the temperature may be determined by increase in resistance.

GERMANY. Exciting coils and stationary windings by increase in resistance, other parts by thermometer.

GREAT BRITAIN. Stationary windings by increase in resistance. Moving coils by increase in resistance, if possible, otherwise by thermometer or thermo-couple. Commutators, brushes, bearings by thermometer.

SWEDEN. Windings by increase in resistance, if possible, otherwise by thermometer. Other parts by thermometer.

UNITED STATES. By thermometer. Conductors by rise in resistance, when possible.

Duration of Test

BELGIUM.

Continuous service. A period of sufficient duration to attain a practically constant temperature: ordinarily 5 hours up to 20 kilowatts, 8 hours above 20 kilowatts.

Intermittent service. One hour.

Momentary service. The number of hours indicated on the name-plate.

FRANCE.

Continuous working. A period sufficiently long to attain a practically constant temperature. (See Note.)

Intermittent service. One hour.

NOTE.—FRANCE. The periods are given, in a general manner, by the following table:

$$K = \frac{\text{Volts} \times \text{Amperes}}{\text{Rev per min.}}$$

K		K	
0- 10	2 hours	200- 500	7 hours
10- 30	3 "	500- 750	8 "
30-100	4 "	750- 1,000	9 "
100-200	5 "	1,000-1,500	10 "

Above 1,500, according to the destination of the machine.

GERMANY.

Intermittent service. One hour.

Momentary service. The number of hours indicated on the name-plate.

Continuous service. Ten hours.

In the case of small machines the duration of test may be reduced.

GREAT BRITAIN.

Continuous working. Six hours (up to 1,000 kw.).

Intermittent working. One hour (under revision).

SWEDEN.

Continuous service. A period sufficiently long to attain a practically constant temperature.

UNITED STATES.

Continuous service. A period sufficiently long to attain a practically constant temperature.

Intermittent service. According to the conditions of service specified.

Limits of Temperature Rise in Deg. Cent.

BELGIUM.

(i) *Permissible limits.* (ii) *Recommended limits.*	(i)	(ii)
Insulated with cotton	50	45
" " paper	60	45
" " mica, asbestos or similar preparations	80	65
Commutators, brushes	60	50
Bearings, terminals and connections	35	30

For permanently short-circuited windings, 5 degrees rise in excess of the above limits is permitted.

FRANCE.

Continuous service. For stationary windings, 10 deg. cent. in excess of the limits for moving coils.

Moving coils:

Insulated with cotton	50
" " paper	60
" " mica, asbestos or equivalent preparations	80
Iron and bare conductors	90
Commutators	60
Bearings	45

Intermittent service. In conformity with the regulations of the Milan Congress (see *Appendix I*).

Uninterrupted service. For commutating machines destined for an uninterrupted day and night service, the permissible temperature rise shall be in accordance with those for continuous service, reduced by 5 deg. cent.

Association Alsacienne.

(*a*) For field windings traversed by a continuous current:	
By resistance	55
By thermometer	45
(*b*) For all other windings and the iron in which the windings are embedded	45
(*c*) For permanently short-circuited windings	55
(*d*) For commutators, brushes	50
(*e*) For bearings, terminals and connections	30

N. B.—For enclosed machines, an extra rise of 5 degrees may be permitted.

For commutating machines destined to work day and night continuously the above limits of temperature shall be reduced by 5 degrees.

GERMANY. For stationary windings 10 deg. cent. above the limits for moving coils is permitted.

For moving coils as well as the iron in which the windings are embedded:

Insulated with cotton	50
" " " under oil and paper	60
" " enamel, mica, asbestos or equivalent preparations	80

Commutators	60
Bearings	50

GREAT BRITAIN. For cotton, paper and its preparations, linen, micanite or similar materials:

Stationary coils (by increase in resistance)	60
Moving coils (by increase in resistance)	60
Moving coils (by thermo-couple)	50

SWEDEN. For stationary windings, 10 per cent above the limits for moving coils.

Moving coils:

Insulated with cotton	50
" " paper	60
" " mica, asbestos	80
Coreplates	60
Commutators	60
Bearings	40

UNITED STATES.

Field and armature windings	50
Commutators and brushes	55
Bearings and other parts	40

N. B.—For large machines, a temperature limit of 40 deg. cent. under rated load conditions and 55 deg. cent. under overload is frequently specified.

Surrounding Air Temperature

(At the commencement of each paragraph the figure in deg. cent. indicates the standard adopted as the room temperature.)

BELGIUM.

35 deg. cent. The temperature to be adopted is the mean of the thermometer readings, taken at regular intervals during the last quarter of the test, in the currents of air passing to the apparatus, or, in default, at the middle height round the apparatus; in any case, as near as possible at a minimum distance to ensure safety from the effects of direct radiation.

FRANCE.

35 deg. cent. The thermometer indicating the surrounding air shall be placed in the line of air currents at about one metre from the machine and sheltered from all external influence. The mean value of the figures during the last quarter of the test shall be adopted.

GERMANY.

35 deg. cent. The temperature of the surrounding air shall be taken in the currents of air arriving, or, if there is no well-defined current of air, the mean value shall be taken of the air surrounding the machine at the middle height and at about one metre distant from the machine. The mean value of the figures during the last quarter of the test shall be adopted.

GREAT BRITAIN.

25 deg. cent.

SWEDEN.

35 deg. cent.

UNITED STATES.

25 deg. cent. The surrounding air of the test room is to be ascertained by means of several thermometers protected from direct radiation and air currents.

Heating at Conclusion of Overload Test

BELGIUM. After the application of an overload of 20 per cent for one-fifth of the specified test period and of 40 per cent for three minutes, the prescribed limits of temperature must not be exceeded by more than 10 deg. cent.

FRANCE. No conditions as to heating.

GERMANY. The temperature limits specified for the rated load must not be exceeded, therefore the overload must be applied for a sufficiently short period and at a time when the temperature of the machine is sufficiently low in order to insure that the permissible limits of temperature cannot be exceeded.

GREAT BRITAIN. Under no conditions must the temperature exceed 85 deg. cent.

SWEDEN. ————

UNITED STATES. When the overload test is applied directly after the rated load test under continuous service conditions, an allowance is permitted of 15 deg. cent. above the limits specified for the rated load.

Surrounding Air Temperature Corrections

BELGIUM. If the surrounding air is likely to exceed 35 deg. cent., the temperature limits must be reduced by an amount equivalent to the excess.

FRANCE. If the test is carried out with a surrounding temperature below 35 deg. cent., the temperature limits shall be reduced in the following ratio:

$$\frac{1}{1 + 0.005 \ (35-\theta)}\,.$$

θ being the temperature of the surrounding air during the test.

If the machine is intended for a locality in which the surrounding air exceeds 35 deg. cent., the temperature limits shall be reduced in the following ratio:

$$\frac{1}{1 + 0.005 \ (\theta' - 35)}$$

θ' being the presumed temperature of the surrounding air.

Association Alsacienne. If the temperature of the surrounding air ordinarily exceeds 35 deg. cent., the temperature limits must be reduced by an equivalent amount.

GERMANY. ————

GREAT BRITAIN. If the surrounding air in actual service is likely to exceed 25 deg. cent., the observed temperature rise shall be reduced by one degree for each degree of difference between the surrounding air and 25 deg. cent.

SWEDEN. ————

UNITED STATES. The observed temperature shall be reduced or increased one-half per cent for every degree cent. difference between the surrounding air and 25 deg. cent.

RESISTIVITY OF COPPER

Variation with Temperature

Unless otherwise specified, the following values have been adopted:

BELGIUM. 0.004 per degree cent.

FRANCE. 0.004 per degree cent.

GERMANY. 0.0040 per degree cent.

GREAT BRITAIN. 0.42 per cent per degree cent. from and at 0 deg. cent.

SWEDEN. 0.004 per degree cent.

UNITED STATES. 0.428 per cent per degree cent. from and at 0 deg. cent. for annealed copper of 100 per cent standard conductivity (see *Appendix E*).

ATMOSPHERIC PRESSURE

UNITED STATES. 760 mm. of mercury.

The observed temperature rise shall be reduced by 1 per cent for every 10 mm. deviation below 760. This correction is only to be applied when the atmospheric pressure differs greatly from the standard pressure of 760 mm. of mercury.

MECHANICAL TESTS

BELGIUM. Machines must be capable of withstanding for five minutes, at no load with and without excitation, a speed of 25 per cent in excess of the maximum speed specified for the particular service, unless the nature or method of using the machine in itself necessitates speeds exceeding this figure, in which case the excess must be 100 per cent.

FRANCE. Generators must be capable of withstanding a momentary increase in speed to be fixed, in each case, according to the particular method of driving. Continuous current motors must be capable of withstanding, during five minutes, a speed of 20 per cent in excess of the rated speed.

Association Alsacienne. Motors must be capable of withstanding, during five minutes, a speed of 30 per cent in excess of the rated speed.

GERMANY. Machines intended to work at a practically constant speed must be capable of withstanding during five minutes, a speed of 15 per cent in excess of the rated speed, first without excitation and then with full excitation.

GREAT BRITAIN. ———

SWEDEN. Machines must be capable of withstanding a speed of 20 per cent in excess of the rated speed. Generators driven by hydraulic turbines, unless otherwise specified, must be capable of withstanding a speed of 90 per cent in excess of the rated speed.

UNITED STATES. ———

EFFICIENCY

General Conditions

BELGIUM. The method of determination is to be specified. Unless otherwise stated, the efficiency is to be ascertained at rated load and under the corresponding conditions as to temperature.

The power absorbed in the field rheostats of a machine is to be included as part of the power required to excite the machine. In the case of a separately excited machine, the efficiency of the machine and that of its exciter, shall be separately stated.

FRANCE. The efficiency tests should be made at, or reduced to, the temperature attained at the close of the working test. The efficiency shall be stated for the rated load, three-quarters and half load, and is to include the losses due to the auxiliary apparatus such as exciter, ventilation, circulating pumps, forming an integral portion of the plant.

GERMANY. The statement as to the efficiency applies to the rated load and the conditions of service to which it refers is to be mentioned. The power absorbed in excitation and in the rheostats must be considered as losses for the purpose of the calculations; unless otherwise stated the power absorbed in cooling the machine must also be considered as a loss.

For machines which are specially excited, the efficiency of the two machines must be stated separately.

GREAT BRITAIN. ———

SWEDEN. The losses in excitation and in the rheostats are to be included.

Friction losses are only to be included in the case of machines with automatic lubrication.

Losses due to an independent flywheel are to be excluded.

The efficiency measurements are to be made at the temperature attained by the machine at the close of the rated load test and referred to a surrounding air temperature of 20 deg. cent.

UNITED STATES. The test is to be carried out under ordinary working conditions and with the surrounding air at standard temperature.

In the case of belt-driven machines, the loss of power in belts and the increase of bearing friction due to the increase of belt tension, is to be excluded.

In the case of a generator inseparable from its prime mover, bearing friction is to be excluded.

The losses in exciters or in auxiliary apparatus are to be considered separately, and charged to the plant consisting of the machine together with its auxiliary apparatus.

The plant efficiency is to be distinguished from the efficiency of the machine alone. The efficiency of a machine is to be measured at, or reduced to, the temperature which the machine assumes under rated load conditions, referred to a surrounding air temperature of 25 deg. cent.

Method

ALL COUNTRIES. Directly by input output, where possible.
Indirectly by losses, if the direct method is not possible.

Enumeration of Losses

BELGIUM. ————

FRANCE.

Mechanical. (*a*) Bearing friction and ventilation.
(*b*) Friction of brushes on commutators and collecting rings.

Electrical. (*c*) Hysteresis and Foucault currents.
(*d*) Joule effects in the circuits.

GERMANY. The losses are not enumerated in tabular form.

GREAT BRITAIN. ————

SWEDEN.

(*a*) Bearing, brush and air friction.
(*b*) Hysteresis and Foucault currents.
(*c*) Ohmic losses in armature.
(*d*) Ohmic losses in brushes.
(*e*) Ohmic losses in exciting coils.

UNITED STATES.

(*a*) Bearing friction and windage losses.
(*b*) Molecular magnetic friction and Foucault current losses.
(*c*) Armature resistance losses.
(*d*) Commutator-brush friction loss.
(*e*) Brush and brush-contact resistance losses.
(*f*) Field excitation loss.
(*g*) Load losses.

NOTES.—FRANCE. *Association Alsacienne* includes under electrical losses brush contact resistance.

UNITED STATES. (*e*) Losses may be considerable with carbon brushes in low voltage machines. (*g*) Difference between total losses under load and sum of losses as here specified.

DIELECTRIC TESTS

General Conditions of Test

BELGIUM. Dielectric tests take the place of insulation tests unless the machine is intended for localities in which special conditions are imposed.

The test is to be carried out before the machine is put into actual service. The repetition of the test is to be avoided.

The test is to be carried out hot.

The windings of machines and transformers must be capable of withstanding, for a period of half an hour, a working pressure of 30 per cent in excess of the highest pressure of the service.

FRANCE. The test of the insulation is to be carried out hot, when possible, and shall only be made in the works of the manufacturer.

The test pressure is to be applied gradually. The circuits of machines and transformers shall be capable of withstanding, without undue strain, for a period of three minutes, a pressure 30 per cent in excess of the ordinary working pressure, provided no mechanical or electrical considerations are against it.

GERMANY. The tests, when possible, are to be carried out at the works of the manufacturer. They are not to be repeated except in very exceptional cases. For large machines the test is to be repeated, *in situ*, but previous to the machine being put into actual service.

The test is to be carried out hot. Machines and transformers must be capable of withstanding, during five minutes, a pressure 50 per cent in excess of the rated pressure.

GREAT BRITAIN. ———

SWEDEN. The test to be carried out hot.

UNITED STATES. In general, the test is to be carried out at the temperature corresponding to the rated load and when the machine is completely assembled, but before it is put into regular service.

The machine must be dry and free from dust.

Points of Application of the Pressure

ALL COUNTRIES. The various rules specify that the test pressure is to be applied between windings and the frame and between all electric circuits.

Nature of the Test Pressure

BELGIUM, FRANCE, GERMANY, SWEDEN. The values of the test pressure herein indicated are applicable to cases in which the testing current is similar to the ordinary working current.

If windings intended for continuous current work be tested with alternating current, the test pressure shall be seven-tenths of that specified.

Conversely, if windings intended for alternating current work be tested with continuous current, the test pressure shall be 1.4 times that specified.

The voltage curve of the alternator employed for the test shall be as nearly as possible a sine wave.

GREAT BRITAIN. ———

UNITED STATES. The test is to be carried out with alternating current at the normal frequency of the apparatus.

The values herein given are the root mean square values of the test pressure referred to a sine wave form.

The wave shape of the test pressure should be as nearly as possible sinusoidal, and should not be materially distorted by the testing circuit.

Test Pressure

BELGIUM.

Working Pressure.	Test Pressure.
Less than 300 v.	4 times the working pressure + 300 v.
300– 600 v.	3 " " " " + 600 v.
600– 1,200 v.	2,400 v.
1,200– 5,000 v.	Twice the working pressure.
5,000–10,000 v.	The working pressure + 5,000 v.
Above 10,000 v.	1.5 times the working pressure.

FRANCE.

Rated Pressure.		Test Pressure.
Up to 5,000 v.	Tested Hot.	Twice the rated pressure with minimum of 110 v.
From 5,000–10,000 v.		Rated pressure + 5,000 v.
Above 10,000 v.		1.5 times rated pressure.
Up to 5,000 v.	Tested Cold.	Three times the rated pressure with minimum of 500 v.
From 5,000–10,000 v.		Rated pressure + 10,000 v.
Above 10,000 v.		Twice the rated pressure.

GERMANY.

Rated Pressure.		Test Pressure.
Above	40 v.	At least 110 v.
From 5,000 -	7,500 v.	The working pressure + 7,500 v.
Above	7,500 v.	Twice the working pressure.

GREAT BRITAIN. ————

SWEDEN.

Working Pressure		Test Pressure.
Up to	3,300 v.	3 times the working pressure with a minimum of 700 v.
Above	3,300 v.	1.5 times the working pressure.

UNITED STATES OF AMERICA.

Working Pressure.	Power.	Test Pressure.
Not exceeding 400 v.	Below 10 kw.	1,000 v.
	10 kw. and above.	1,500 v.
400 v. and above, but less than 800 v.	Under 10 kw.	1,500 v.
	10 kw. and over.	2,000 v.
800 v. and above, but less than 1,200 v.	Any power.	3,500 v.
1,200 v. and above, but less than 2,500 v.	"	5,000 v.
2,500 v. and over.	"	Double the normal rated voltage.

Length of Test

BELGIUM. 30 minutes.

FRANCE. 30 minutes (hot) / 5 " (cold) } (*Association Alsacienne*, 5 minutes).

GERMANY. 1 minute.

GREAT BRITAIN. ————

SWEDEN. At least 1 minute.

UNITED STATES. 1 minute.

APPENDIX I.

HEATING (see p. 43).

STIPULATION OF THE MILAN CONGRESS (September, 1906).

The heating of a motor is to be considered as excessive when, starting from a surrounding air temperature equivalent to 25 deg. cent., the motor, after 10 hours' working at its permanent power or after one hour working at its normal power, attains a final temperature exceeding that of the surrounding air by the following values:

(*a*) For windings insulated with cotton. . . . . 70 deg. cent.
For windings insulated with paper. . . . . 80 " "
For windings insulated with mica, asbestos or other substances presenting the same qualities of insulation and incombustibility. . . . . 100 " "

(*b*) For commutators. . . . . 80 " "

(*c*) For metallic portions in which the windings are embedded, the value corresponding to that indicated for the windings, according to the insulation employed for the latter.

When the windings are insulated with a combination of insulating materials, the lower limit will be taken. . . . By permanent power and normal power of a motor is to be understood that power which, the current being furnished at the normal pressure of supply, can be developed by the said motor during 10 consecutive hours, in the first case, and during an uninterrupted period of one hour, in the second case, without the heating being excessive in the sense indicated under the paragraph as to " Heating."

TOLERANCE AS REGARDS GUARANTEES

UNION DES SYNDICATS DE L'ELECTRICITÉ

The following table fixes:

(1) Tolerance allowed for errors in measurement, and beyond which the question as to reduction in price may arise.

(2) The limit beyond which the question as to the material not complying with the specification may arise.

Guarantees as to	Tolerance.	Limits.
Heating.	3 deg. cent.	10 deg. cent. above the limits fixed.
Auto-regulation.	20% of the guaranteed percentage.	50% of the guaranteed percentage.
Efficiency.	20% of the sum of the total or measurable losses, as the case may be.	50% of the losses, total or measurable.

ASSOCIATION ALSACIENNE

As acceptance of the various guarantees given, it is usual to fix two limits, the first representing the permissible tolerance to allow for inexactitudes and errors of measurement, the second giving to the buyer the right to reject the material. Between these two limits it is usually a question of penalties in proportion to the deviation from the guarantee. The penalties for the different guarantees are cumulative.

The following values are to be recommended:

Guarantee as to	Tolerance re Measurements.	Limits of Rejection.	Penalties to be applied by the Buyer, between the Tolerance and Limits.
Heating.	4 deg. cent. above limits fixed (for resistance measurements only).	10 deg. cent. above limits fixed.	½% per degree.
Auto-regulation.	15% of the percentage guaranteed by the manufacturer.	40% of the guaranteed percentage.	1% for each 10% of the percentage guaranteed, applicable between 15% and 40%.
Efficiency.	15% of the sum of the losses, total or measurable, as the case may be.	40% of the losses, total or measurable.	2% for each 10% of the sum of the losses, total or measurable, applicable between 15% and 40%.

25¢